THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

The Annual Dinner

THE address on What Sells Motor-Cars, made by R. H. Grant at the Annual Dinner on Jan. 13 in New York City, will be found on p. 270. Everyone interested in any phase of automotive engineering should read this speech. A more clear, concise statement of the fundamentals of success in motor-car merchandising will probably never be heard.

Suggested European Trip

VARIOUS events of interest to the members will be held in Europe in the fall. These are the automobile shows, including those at Paris and London, and the Commercial Motor Transport Exhibition in London. Members who are contemplating a trip abroad to attend the shows, or would like to join a party if one is organized to make the visit, are asked to communicate with the office of the Society, as interest in the subject has been expressed in various quarters.

The Need for Shop Apprentices

AT the Annual Meeting, H. A. Frommelt stated in a very forceful manner that there is great need for the inaugurating of rational apprentice-training in the automotive industry. He expressed the opinion that the present number of apprentices is not 10 per cent of what it should be. He criticized severely the current condition so far as the servicing of motor-vehicles is concerned. He has gathered from his experience that an adequate supply of apprentices would be forthcoming if suitable training-methods were put into effect; that is, the qualified men are not really unduly partial to white-collar jobs. Mr. Frommelt's views are worthy of most serious study. What he had to say in his paper at the Annual Meeting will be set forth comprehensively in an early issue of THE JOURNAL. A news account of the Training Session at Detroit in which he participated is included in this issue.

The News Story of the Annual Meeting

BEGINNING on p. 166 of this issue, the news story of the Annual Meeting will be found. This account covers the complete meeting, the papers not printed in full being abstracted or reported extensively.

Of the 24 papers presented, 11 are printed in full in this issue and 5 are covered in a comprehensive manner in the news story of the meeting. The discussion of 6 of the papers is reported in full in the news story, and the discussion of the other papers will appear in early issues of THE JOURNAL.

In order that the news account might be as accurate as possible, the members taking part in the discussion at the different sessions were asked to correct the stenotype reports of the discussion, which were available immediately after each session. While the original copies of the stenotyped reports were sent to New York City for the writing of the session reports, copies were held throughout the meeting for correction by discussers. It is hoped that this method of having discussers approve their remarks will accelerate the publication of discussion at the National meetings.

French Lick Summer Meeting Place

THE 1927 Summer Meeting of the Society will be held at French Lick Springs, Ind. Announcement to this effect was made some months ago but, in view of strong protests made by members residing in the East that the meeting should be held in their territory, the matter was considered again very thoroughly by the Meetings Committee and the Council, with the result given above. The argument of the Eastern members is that, inasmuch as the Annual Meetings of the Society have been held regularly in Detroit in recent years, the situs of the Summer Meeting, as a matter of fairness, as well as of convenience to the Atlantic seaboard contingent, should be in the East.

Accommodations for upward of 1000 persons are needed for the Summer Meetings. There are few available places so far as quality, accessibility and facilities are concerned. Before the final decision was made to hold the meeting at French Lick Springs this year, uptodate information as to the availability and facilities of all places in the East, including Canada, that had been mentioned in discussion by many members was secured and tabulated. This was considered at the sessions of the Sections Committee and the Meetings Committee held in Detroit at the time of the Annual Meeting. Each of the Eastern Sections had been asked to make recommendation as to the place. The replies received were of course duly considered by the Committees, and the Council, in making the final decision. Much thought was

given to the subject and it is trusted that the decision will be satisfactory to the members in general. The Meetings Committee will welcome advice from members as to where Summer Meetings of the Society should be held after this year.

Engineering Trends in New Cars

RECENT engineering developments as embodied in passenger-car models for 1927 are reviewed comprehensively by Austin M. Wolf, consulting engineer, of New York City, in the Automotive Research section of this issue of THE JOURNAL on p. 195. This review is noteworthy and valuable because it is a careful analysis by one who is competent to perform the task, indicates to what extent the results of research and development work are being incorporated into actual practice and reflects the trends of improvement. The study includes foreign as well as American cars.

Of special interest in connection with this review is the table of specifications of the "composite," the "ideal" and the "typical" American family-car as given on p. 198 in the report of the Metropolitan Section automobile-show dinner-meeting of Jan. 10. The close correspondence of the three sets of specifications is remarkable, as the "typical" car, which represents the majority ideas of designing engineers, so closely meets the preferences of a majority of the operating-engineer members of the Metropolitan Section who returned questionnaires in the Composite-Car Contest conducted by the Section during last October, November and December.

Transmission-Chain Sectional Committee Organized

THE first meeting of the Sectional Committee on Transmission Chains and Sprockets organized under the procedure of the American Engineering Standards Committee and sponsored by the American Society of Mechanical Engineers, the American Gear Manufacturers Association and the Society, was held in New York City recently. The scope of the Committee as outlined in the 1926 Year Book of the American Engineering Standards Committee is the formulation of American Standards for transmission roller-chains and sprocket teeth, based on the standards already adopted by the sponsor Societies; and the study of the possibilities of standardizing the so-called silent type of transmission chain and sprocket.

Following a review of the circumstances leading to the organizing of the Committee and the procedure for its work and the approval of its reports, H. V. Hetzel was elected temporary chairman, and G. M. Bartlett, temporary secretary. After a brief discussion of the standards that have already been adopted for transmission chains, it was decided to divide the work into two groups with a Subcommittee for each, namely, the Subcommittee on Roller-Chain Standardization, with G. M. Bartlett as chairman, and the Subcommittee on Silent-Chain Standardization, G. A. Young being chairman. The Subcommittees are to gather all available data on their respective types of transmission chain and sprocket used in all mechanical industries, preparatory to drafting reports for submission to the Sectional Committee. It was felt that a large part of the standardization program for roller chains has already been accomplished and that the principal work to be done by the Sectional Committee is on silent-chain standardization.

Part II, 1925 Transactions

AS this issue of THE JOURNAL goes to press, work in preparing the TRANSACTIONS for the last half of 1925 is actively under way both at the printer's and in the office of the Publication Department. This volume, which it is expected will be available about April 15, will consist of approximately 928 pp. and will contain papers presented at the 1925 Semi-Annual, Aeronautic, Production, Automotive Transportation and Service Meetings of the Society, other papers presented at Sections Meetings and contributed articles that were published in THE JOURNAL from July to December, 1925, inclusive, comprising a total of 43 papers and articles including discussions.

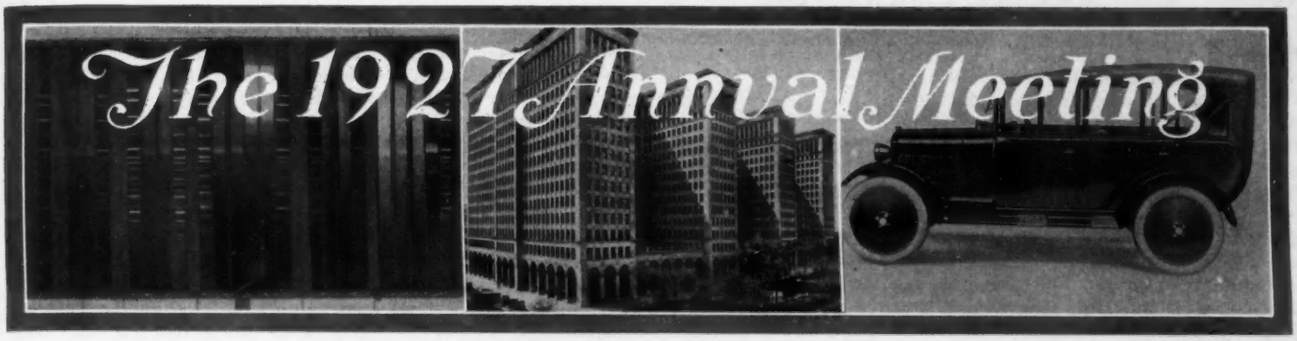
Volumes of the TRANSACTIONS are now sent only to members ordering them and paying the fee of $2 per Part. To be assured of receiving a copy of this Part, members should place their orders by March 12. An order blank was enclosed with the *Meetings Bulletin* of Jan. 17. For the convenience of the members who may have mislaid or overlooked this blank, a TRANSACTIONS order blank will be found in the advertising section on p. 126.

To meet the wishes of members who desire to place a single order to cover all future Parts of TRANSACTIONS, instead of ordering each Part separately, a space is provided in this blank for such orders. These will be entered on a list to receive Parts of TRANSACTIONS as they are issued. Payment at the rate of $2 per Part for all copies ordered in this way is to be made upon presentation of a bill prior to the appearance of each Part.

The Annual Meeting

THE 1927 Annual Meeting has become history, but through the pages of THE JOURNAL it will serve as another guide-post in the advance of automotive engineering. The standard of the papers presented at the technical sessions was unusually high and many of the sessions brought out exceptionally interesting and valuable discussion. Eleven sessions were held during the 4-day meeting, the actual attendance being 818. The total attendance at the sessions was 2450, an average of 222 per session. This compares favorably with the total session attendance of 2500 at the 1926 Annual Meeting, at which the actual attendance was over 900. The Meetings Committee believes that the attendance at the sessions confirms their judgment in deciding on the topics for the several sessions and in selecting the speakers, all of whom were recognized as authorities in their respective fields.

The Annual Meeting officially closed at 3 a. m., Saturday, after the most successful Carnival in the Society's history. As predicted by the Carnival Committee, which was under the able chairmanship of E. V. Rippingille, every available seat in Oriole Terrace was sold several days before the Annual Meeting started and the day of the Carnival found a waiting-list of over 60. The attendance of 1152 far exceeded that of previous years, establishing a record that will be difficult for future Carnival Committees to break.



FESTIVAL SPIRIT REIGNS SUPREME

Prevailing Optimism Voiced in Automotive Forecast Made at Annual Dinner

Comprehensive opinions forcefully expressed by the distinguished speakers at the Annual Dinner combined to create in the minds of the privileged listeners a feeling not only of optimistic confidence in themselves as automotive engineers but a similar feeling with regard to the future of the automotive industry. The dinner was held at Hotel Astor, New York City, on Jan. 13, and more than 1100 members and guests partook of it. The brief business session was concerned only with the announcement by the tellers of election of the name of the newly elected President of the Society, J. H. Hunt, and of the names of the other officers and councilors for the coming year. It was then adjourned to be reconvened at Detroit on Jan. 25.

Following a delightful organ recital by Maurice Garabrant during the preliminary reception, a trio of Highlanders in full Scottish regalia marched hither and yon throughout the reception rooms and the grand ballroom wherein the banquet was to be held, and the members and guests assembled at the tables assigned them to the inspiriting music of bagpipes and drum. The soft light from the shaded chandeliers and the shaded candles on the flower-bedecked tables enhanced the beauty of the ornate gilded balconies and other decorative features, making them all seem even more resplendent, and the movement of the seeming multitude of people who were seeking their proper seats furnished just the right degree of action to transform the scene into an unforgetable moving picture. Enlivening music was rendered at intervals during the dinner by the Wolfsie Orchestra, and Frank Sherman helped the throng to whoop things up by leading the singing of the Songs of the Sections.

Remarks of President Litle

In his opening remarks the retiring President, T. J. Litle, Jr., said that the commercial supremacy of the automotive industry has been dependent largely upon the engineering work done by the industry, work that becomes increasingly more important each year. He compared the pioneer spirit of adventure of "prairie-schooner" days with that of the engineer today along lines of automotive research in the interests of transportation having maximum efficacy, and cited a recent automobile trip he made through five States in 1½ days to illustrate by contrast the startling progress due to this adventurous spirit, indicating also that further startling progress will result. Before introducing the toastmaster, Hon. E. P. Warner, Assistant Secretary of the Navy for Aeronautics, President Litle expressed his gratefulness to the other officers of the Society and to its members for their wholehearted cooperation throughout his term of office.

Responding with his usual easy grace to President Litle's introduction, Toastmaster Warner remarked the fact that for 20 years the Society has constantly extended its service to the industry and has as constantly entered new fields of usefulness, thereby justifying its record for sustained performance. This record excels, he said, that of the airplane pilot who made a forced landing and was reported by the local newspaper as "a pilot who has been flying continuously for 3 years and this is the first time he has ever had to land." He then introduced President-Elect J. H. Hunt.

President Hunt's Address

Expressing his appreciation of the honor of having been elected to the presidency, Mr. Hunt went on to say that the work of the Society is based very largely upon the effective work of its committees, but that the activities of the Sections also constitute a most important phase. He urged all members to intensify their interest and their effort in Section work.

Reviewing the history of automotive development, the speaker referred to the time when an insatiable public-demand for the automobile was evidenced, a time when the financiers of the industry turned to the production men and placed them in the saddle, but he referred also to the engineers of that period who were thereby hampered in their desires to develop the refinements of the automobile that they believed would be essential in course of time.

Although Mr. Hunt said that the industry has reached a status in production ability wherein it can build more cars than it can sell, he believes that such so-called "saturation" as now exists is not important and regards the present situation as merely a shift from a "buyer's" to a "seller's" market. The car that can be sold is the car the customer wants, and it is not the car that happens to be the one most convenient to offer for sale. With sales managers instead of production managers in charge, he remarked, automotive engineers will still have a busy time of it; but it will be a different kind of a busy time.

Commenting upon phases of advertising and of sales work that have significance for the engineer, criticism was directed by Mr. Hunt against arrogant advertising that practically claims super-perfection for the product; unless the engineering department has previously, in instances like this, backed up such claims with actualities of performance, its personnel will thereafter, in Mr. Hunt's opinion, be very busy engineers indeed. The present and future demands created by

THE ANNUAL MEETING NEWS ACCOUNT

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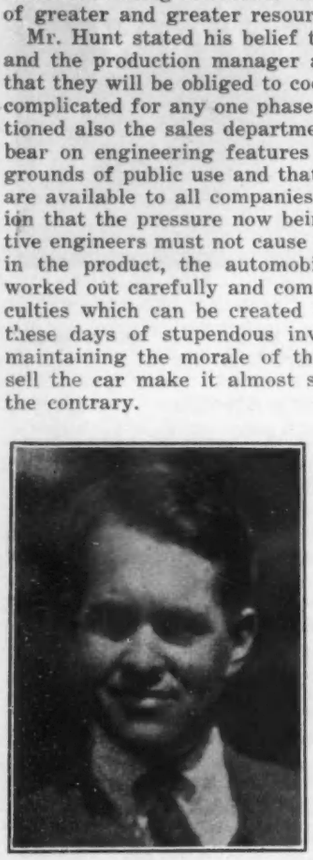
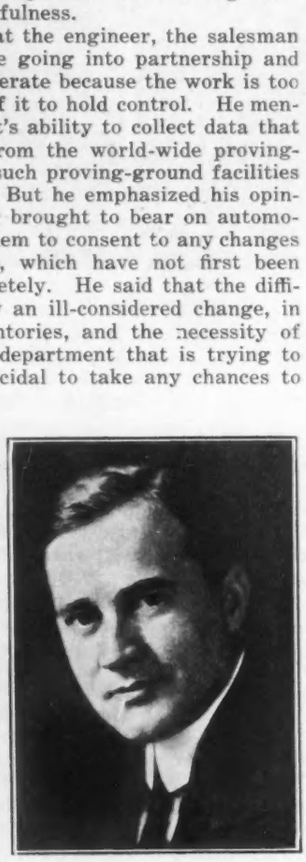
increased selling-resistance will require automotive engineers of greater and greater resourcefulness.

Mr. Hunt stated his belief that the engineer, the salesman and the production manager are going into partnership and that they will be obliged to cooperate because the work is too complicated for any one phase of it to hold control. He mentioned also the sales department's ability to collect data that bear on engineering features from the world-wide proving-grounds of public use and that such proving-ground facilities are available to all companies. But he emphasized his opinion that the pressure now being brought to bear on automotive engineers must not cause them to consent to any changes in the product, the automobile, which have not first been worked out carefully and completely. He said that the difficulties which can be created by an ill-considered change, in these days of stupendous inventories, and the necessity of maintaining the morale of the department that is trying to sell the car make it almost suicidal to take any chances to the contrary.



E. P. Warner



R. H. Grant

THE TOASTMASTER (LEFT) AND THE PRINCIPAL SPEAKER (RIGHT) AT THE ANNUAL DINNER

As the problems of the industry at present seem to be principally those of refinement rather than those of the development of inventions, the speaker pointed out that the work of the younger automotive engineers has a tendency to become more and more specialized and that they thus will have opportunities to do important work much earlier in their careers than was true formerly. But he said that unless they have the type of mind which delights in knowing all there is to know about some one detail, their opportunities will be very limited unless they keep abreast of current events in the industry and maintain a broad viewpoint.

WHAT SELLS MOTOR-CARS

Toastmaster Warner introduced the next speaker, R. H. Grant, as a man who has witnessed not only the extension of scientific methods into the study of selling methods but also the effects which have resulted. Mr. Grant's address on the foregoing subject is printed in full elsewhere in this issue of THE JOURNAL.

"KET" RISES TO THE OCCASION

In his well known inimitable manner, a human-interest manner that compels one's mind to retain the fundamentals of his remarks, C. F. Kettering responded to the toastmaster's invitation and broadcasted a few more Ketterisms. He reminded his hearers that, in spite of lugubrious predictions each year to the effect that the automobile business for the coming season is to be "not so good," each year has seen the business become better. "If you 'sell' a man an automobile he has a right to kick about it, but if he 'buys' it, then it's his own fault," and tied this little bundle up with the remark that the industry has reached the point at which its product, the automobile, actually is good enough to be "sold" to the public.

Referring to car depreciation and to criticism that this has been made excessive in effect, due to continual yearly changes in car models that induce the scrapping of the cars already owned and the buying of new cars, the speaker brought out the fact that the engineers of the industry do not change the old models. They simply change the prospective new models and thus, by creating a reasonable degree of owner dissatisfaction, merely change the owner-public's mind. On this point he remarked:

> Even though depreciation may be $100 more than that on a time-mileage basis, that is not the fault of the designer. All we have done is to change the owner's mind and it is worth $100 to change anybody's mind. That is what keeps the automobiles on the road and keeps the business going.

HUNT BECOMES PRESIDENT

At the 1927 Dinner, which was held at the Hotel Astor, New York City, on Jan. 13, the result of the election of officers to serve during the administrative year beginning at the close of the 1927 Annual Meeting of the Society in Detroit was announced. F. K. Glynn, chairman, A. C. Bergmann and L. Clayton Hill, who constituted the tellers of election, reported that 1021 ballots had been cast. The result of the election, with a few scattering votes, was as follows:

President	
J. H. Hunt	1021
First Vice-President	
W. G. Wall	1013
Second Vice-President Representing Motor-Car Engineering	
F. M. Zeder	1019
Second Vice-President Representing Tractor Engineering	
J. F. Max Patitz	1020
Second Vice-President Representing Aviation Engineering	
E. T. Jones	1019
Second Vice-President Representing Marine Engineering	
Paul G. Zimmerman	1021
Second Vice-President Representing Stationary Internal-Combustion Engineering	
C. B. Jahnke	1020
Councilors	
S. W. Sparrow	1019
Ernest Wooler	1019
C. B. Veal	1018
Treasurer	
C. B. Whittelsey	1021

The Constitution of the Society provides that in addition to the officers elected at any Annual Meeting the President and the three Councilors elected at the Annual Meeting of the previous year shall be members of the new Council. In accordance with that provision Past-President Litle and Councilors Chandler, Winchester, and Milton will serve as members of the 1927 Council. The photographs and sketches of the lives of the members of the new Council will be found on p. 230.

OVER 800 ATTEND DETROIT MEETING

Sessions All Well Attended and Carnival Breaks Record

The interest of the members in the technical sessions at the Annual Meeting in the General Motors Building, Detroit, on Jan. 25 to 28, as evidenced by the attendance definitely confirmed the belief of the Meetings Committee that the program of papers and demonstrations arranged for the meeting was exceptionally good. The actual attendance at the entire meeting, with the exception of the Air-Travel

Session and the Carnival, was 820 and the total attendance at all the sessions was over 2400. The attendance at the Carnival was 1152, a record for this event.

The Air-Travel Session on Tuesday evening, which followed immediately after the Business Session, was possibly the most interesting. Although it had not been announced in the MEETINGS BULLETINS that Sir Alan Cobham would speak at the Air-Travel Session, owing to his acceptance of the invitation of the Meetings Committee to attend the Annual Meeting and the Carnival being received only a few days before the Meeting, it was possible to send a special announcement to the members in Michigan, Indiana, and Ohio. The Session was very well attended by the members and their wives, over 400 being present.

If attendance is any criterion, the technical sessions on Thursday and Friday were the most interesting. The Mystery Session filled every available seat and made it necessary for over 50 members to stand. The addresses at this session were of exceptional interest and although they are summarized in this news account of the Annual Meeting, members should read the full addresses which will appear in an early issue of THE JOURNAL.

Without doubt the single paper that created the most comment was The English Light Car and Why by Alan R. Fenn who came to this Country at the invitation of the Meetings Committee for the express purpose of presenting this paper. The paper and the discussion brought out many points of vital interest in the application of the light car to American conditions. This paper will be found on p. 203 and the summary of the discussion on p. 190.

During the Annual Meeting a breakfast or luncheon conference was held at the General Motors Building before each session for the chairman, the speakers and the members who had submitted written discussion. These conferences, besides affording an opportunity for the principals at each session to meet in an informal manner, made it possible to arrange the session schedule with full regard to the material to be presented.

RESEARCH COMMITTEE EXPANDS

Adds to Membership, Reorganizes Subcommittees, Considers Extending Activity

The Research Committee, at its meeting on Tuesday morning, had for its consideration a larger personnel, the realignment of the subcommittees working on its various projects and the entering on two fields of endeavor not as yet formally covered in its investigations, operation and maintenance and production.

J. F. Winchester, who has been added to the Research Committee for the year 1927, will act as the point of contact between the Research and the Operation and Maintenance Committees, while W. G. Careins and V. P. Rumely, also new members, represent the viewpoints of production men. While no definite plans have been made for investigations into either of these two broad subjects, the desirability of such research and the direction it should take will be taken under more active advisement. The Research Committee has also added to its personnel the following men, whose understanding of the research needs of the automotive industry will make their services of great value to the Committee and to the Society: F. F. Chandler, A. W. S. Herrington, E. R. Hewitt, and John Warner, formerly Research Manager for the Society.

The Riding-Qualities Subcommittee, which has for its mission the study of the factors contributing to or detracting from the comfort of motor-vehicles, will have two new members for the year 1927; Dr. Benjamin Liebowitz, who has for a background many years of study in this field, and John Warner. T. A. Boyd, whose work in the field of fuel chemistry is well known, has been added to the Fuels Subcommittee. The members of this Subcommittee represent the Society on the Cooperative Fuel-Research Steering Committee. The Headlight Subcommittee, whose members constitute the Society's contingent on the Joint Illuminating Engineering Society-Society of Automotive Engineers Steering Committee on Headlight Research, will avail itself of the services of E. S. Marks, C. A. Michel and John Warner, all of whom have contributed actively to the carrying out of this research in the last year. The Society representatives on the Cooperative Committee on Impact Tests remain the same for this year, B. B. Bachman, H. C. Dickinson and C. M. Manly. The other organizations participating in this project are the Bureau of Public Roads and the Rubber Association of America.

J. O. Eisinger of the Bureau of Standards gave an interesting report on the progress being made in the investigation of engine-performance during the acceleration and warming-up period that is now being carried out as part of the Cooperative Fuel-Research. Suggestions were asked for and offered as to the method being followed in this investigation, which consists of comparing the actual torque produced by the engine under various conditions with the maximum torque obtainable under steady running conditions, at the engine-speeds characteristic of the acceleration period. A second topic being studied is the cooling off of an engine when exposed, unprotected, to winter weather conditions. In connection with the fuel-research, a plan was discussed for securing broader publicity for its results. The findings arrived at in this extensive and many-sided investigation will greatly assist in the best use and economy of the Country's liquid fuel resources, provided they are made readily available to those interested in using them and put into such form as to be easily understood. The preparation and distribution of the results of the investigation in such form is now being considered.

Prof. L. C. Lichty, representing Prof. E. H. Lockwood of the Riding-Qualities Subcommittee, may, under present tentative plans, enter on an investigation of the psychological factors affecting the comfort of passengers in motor-vehicles. The vibrating chair that was developed at the Bureau of Standards or some similar apparatus will be used in the contemplated project, to determine what vibrations are commonly considered as disagreeable.

A new activity in the field of highway research is the representation on the Committee on Causes and Prevention of Highway Accidents of the Highway Research Board, for the purpose of maintaining contact with the work of this body. C. B. Veal was appointed to represent the Society in this connection.

J. H. Hunt reported briefly on the progress of the headlight research being carried out under the joint auspices of the Illuminating Engineering Society and this Society. He pointed out that so far 14 of the test-equipments developed by the joint committee have been distributed to those interested in experimenting with them. Weather conditions will probably prohibit, until the middle of April, the holding of the proposed demonstration at the General Motors Proving Grounds, of ideal lighting distributions obtained by experimenters with the equipment. In the mean time, a series of tests designed to throw light on the fundamentals of headlighting will be drawn up and proposed for execution to the owners of the test equipment.

MANPOWER DEVELOPMENT ESSENTIAL

Need for Automotive Apprentices and Systematic Training Layout Stressed

Considerations regarding the failure of trade-schools as an entity, the success of community training-courses and the growth of cooperative education constituted phases of the well-attended Training Session that was held in the afternoon of Jan. 25. The two papers that were presented elicited much worthwhile discussion during which many of the main points were amplified and additional phases of the subjects were treated. The paper by H. A. Frommelt was presented first, mainly in abstract form, its title being A Comprehensive Apprenticeship Program for the

H. A. Frommelt Albert Sobey

THE AUTHORS OF THE TWO TRAINING SESSION PAPERS

Automotive Industry. The second paper had for its title Manpower Development for a World-Wide Organization and was presented by Albert L. Sobey, director of education of the Flint Institute of Technology. The latter paper is printed in full elsewhere in this issue of THE JOURNAL. Louis Ruthenberg was chairman of the session.

APPRENTICESHIP PROGRAM

In presenting his subject, Mr. Frommelt stated that automotive apprenticeship is not only a possibility but an actuality, since the results of experience already have proved its necessity and value. He believes that one of the greatest future developments in the automotive field will take place through the training of personnel. The good effect of a comprehensive and adequate personnel-training program upon the industry as a whole is, in his opinion, more a certainty than a matter of speculation. He stated that apprenticeship for the most neglected field, that of service, depends largely upon the impetus of example set by the manufacturer in addition to dependence upon the actual support of such a program.

Outstanding examples of success of the personnel training in the automotive field prove by facts the possibility of a comprehensive application of apprenticeship in the industry, said the author. He summarized the results that can be expected from an adequate program of apprenticeship training as follows:

(1) A sufficient number of tool-makers, machinists, die-sinkers, and the like
(2) The creation of a supply of trained personnel that can be shunted into engineering, drafting, servicing, and supervisory departments and into other positions as needed
(3) The stabilization of the working force
(4) The reduction of labor turnover, because the saving effected in this manner is in itself compensated for by the cost of the training
(5) The formation of the best defense possible against adverse economic doctrines, through education of the backbone of an organization
(6) Apprenticeship training constitutes a key with which to unlock the gates to the most fertile field in the automobile world, namely, the adequate servicing of automobiles

In developing the subject Mr. Frommelt presented statistical data quoted from the reports of the Federal Department of Education regarding the spread of education in this Country, tending to show that for every 100 children, male and female, in the sixth grade only 67 graduate from the eighth grade. Of these 67 only 34 enter high school, and but 14 complete the 4 years' course. Of these 14 students, only 7 enter college and but 2 graduate. He cited the foregoing figures to refute the claims that have been made that industry has suffered from "too much higher education." He said that apprenticeship rightly considered is but a synonym for an industrial activity. Further, that there must be apprentices to be taught, a teacher or a group of teachers to do the teaching and a body of manual operations and related theory as subject matter having a definite trade objective. He then enumerated the essential factors of apprenticeship as being those of (*a*) tradition, (*b*) education and (*c*) solidarity. Following an elaboration of these factors the speaker took up the special application of apprenticeship training to the automotive industry, treating this subject under the headings of automotive manufacture and automotive servicing, and included also citations of the experience in this regard which several important automobile companies have had to date.

The discussers of Mr. Frommelt's paper included R. E. Plimpton, who spoke regarding means of obtaining closer relations with the various engineering schools; Lieut. W. C. Thee, who outlined the success of personnel training at the Transportation School, Camp Holabird, Md.; John Younger, who emphasized how vital to the industry apprenticeship training is; F. C. Smith, director of technical courses for the International Young Men's Christian Association, who stated that an analysis is now being made of the apprentice-

A CLASS IN MACHINE DESIGN AT THE PLANT OF THE REO MOTOR CAR CO.

ship problem throughout the Country; and by Chairman Ruthenburg, who referred to the difference in the schools of thought that control education and those that control industry, as such, and said that what is needed is a further combination of these schools of thought.

Trade-School versus Engineering Courses and Manpower Supply

Following the presentation of Mr. Sobey's paper, and in addition to other questioners, Earl E. Eby, of the Olds Motor Works, Lansing, Mich., asked the author to differentiate between the trade-school and the regular 4-year engineering-course as they concern a young man who possibly has not definitely decided that he desires to take up any particular

Another Class at the Reo Plant
This One Is Receiving Instruction in Mechanical Drawing

phase of engineering. In reply Mr. Sobey said that the primary aim of the particular course in cooperative engineering to which he refers is to choose from those whose appearance indicates that they have a general background and general aptitude which seem to fit them into a particular line of work and that the endeavor is to develop that kind of man. He cited several instances of actual results of such attempts to determine what the candidate might be best fitted for, as illustrations of how cooperative experience in the shop will help a man to "find himself" early in life.

H. R. Cobleigh, of the National Automobile Chamber of Commerce, suggested what seems to constitute an additional problem that must be considered. He referred to the maintenance field and to the supply of competent mechanics for that field. He said that the production problem is far nearer solution than the maintenance problem and that the former is much easier to solve because it is concentrated in larger plants. He mentioned the fact that there are upward of 80,000 repair-shops in this Country and believed it impossible to put the apprenticeship training plan into effect in such a large number of shops, as has been done in the foundry trade. He suggested also that the nearest approach to success in this direction is attainable through the cooperation of the public schools with the automotive business in the vicinity of these schools. He mentioned an inspection he made of the Cleveland Trade School and said that more work of this type should be inaugurated and prosecuted in the different cities, believing that this is needed before anything like an adequate supply of mechanics is created. He outlined various plans already in process of development which have to do with possible standard courses in training.

BODY DESIGN, BUILDING AND FINISH

Color Harmony Analyzed, Chassis Changes Urged, and Body Production Shown

Study of the combination of colors to produce harmonious and pleasing effects, possibilities and limitations of body design, motion pictures of steel-body production in the new Hudson body plant, and methods of construction of flexible fabric bodies held the interest of 130 attendants at the Body Session on the afternoon of Jan. 25.

The address on Color Harmony, which was given by Arthur S. Allen, of the Ruxton Color Service, presented the color finishing of automobiles in a new light and showed how it can be analyzed mathematically to determine what colors should be used together and in what proportion to use them. The belief of many that startling contrasts that annoy must be used to attract attention is unfortunate; all great colorists make use of small color differences to produce pleasing effects, said Mr. Allen. Two opposite colors, used in the right proportion to make a neutral tone, give a result that is satisfactory to the eye. A car should not be so brilliant as to dominate the landscape nor so subdued that it will not be seen. It should also carry the color that expresses the character of the owner.

Color has three dimensions: hue, or color; value, or amount of light reflected; and chroma, or intensity as related to its opposite color. To demonstrate the principles of color measurement, the speaker used a small globe and asked his hearers to imagine bands of five hues: red, yellow, green, blue, and purple, surrounding it, starting with red at the center and going around clockwise. This, he said, is the hue dimension. The second dimension is that of value, which he assumed to be divided vertically in 10 steps, from white to black. The third dimension is chroma, or intensity, assumed to be graduated in a horizontal direction through the globe, with the brightest color on the outside and the grayest color at the center.

If one takes all the reds he has ever seen or heard of and arranges them in the globe with the lightest ones at the top and the darkest at the bottom and also takes all the reds that have gray in them, which shows the graduation of intensity along the horizontal rod, the arrangement together helps to visualize the three dimensions of color as worked out by Mr. Munsell in studies carried on during 28 years.

The five hues on the globe were arranged so that all were five equal steps of chroma from gray. The colors were not brilliant and when the globe was revolved rapidly they all blended to produce gray.

The five simple colors were then displayed flat on illuminated cards in a black cabinet to give a better understanding of the system. Together with the five simple colors, the five secondary colors, yellow-red, green-yellow, blue-green, purple-blue, and red-purple make the spectrum which for convenience is divided into 10 colors. These 10 colors are placed on the value scale according to their light-reflecting power. Yellow is very powerful and is at the greatest power at the 8 value; red at 4, green at 5, and so on.

Value Scale of the Munsell System

The whole Munsell system rests upon the value scale, and to prove his theory the inventor constructed a photometer with a cat's-eye shutter employing the square of white and black instead of half white and half black, which many physicists have regarded as giving gray. A proportion of 25 per cent of white and 75 per cent of black gives the 5 value of gray. Colors are continually adjusting themselves to the 5 value, declared Mr. Allen, and in paintings and other colored objects that are held to be pleasing, where opposite colors are used, they adjust themselves to the 5-value gray. High and low-value reds also adjust themselves to the 5 value but not to gray. By adjustable colored discs which he placed on a small electric-fan standard and revolved rapidly, Mr. Allen showed how high-value and low-value reds combine to produce gray. A 7-value red and

a 3-value red, whose values added together give a sum of 10 when blended on the spinning disc, give a 5 value of red half way between the 7 and 3 values.

Speaking arithmetically, Mr. Allen said that one red, being 5 steps in gray and of 7 value represented 35, while the other, also 5 steps in gray and of 3 value, represented 15; therefore 15 parts of the former, or high value, balance 35 of the latter, which indicates the proportion in which they should be used.

Chroma, or intensity, was demonstrated by selecting the opposite, or complementary, colors red and blue-green. Ultramarine blue is not the opposite of orange, as used to be taught, but of yellow, said the speaker, and to prove this he asked the audience to look for 10 sec. at a yellow disc and immediately thereafter at a blank sheet of paper. The eye then registered on the paper the opposite color, which was blue-green. A similar test was made with blue and the opposite color, with yellow verging toward red. A 5-value red and a 5-value blue-green mixed to make gray.

The Eye Very Sensitive to Color

To demonstrate to the audience how sensitive the eye is, a disc showing one-half bright red and one-half blue-green was held up and the spectators were asked to vote on which was the more powerful color. Thirteen voted for the red and 14 for the blue-green. The intensity, said Mr. Allen, was exactly balanced and the even division of the vote showed that the eyes measured their intensity correctly. When the disc was revolved rapidly it produced gray.

At the Smithsonian Institute in the City of Washington is a porcelain globe made by Mr. Munsell in Boston on which the primary colors are baked in 5 steps of hues and 10 steps of value and which when revolved is very beautiful.

Next the speaker analyzed several posters and explained how a mass of yellow and a mass of purple at 5 value and 5 steps of chroma balanced to give the neutral gray. The basis of the whole Munsell system, he said, is that when opposites are used, they balance inversely according to the product of their symbols. Thus, a yellow of 8 value and 9 steps in gray or chroma gives a product of 72, while a purple-blue of 3 value and 6 steps in gray gives 18. Hence 18 parts of yellow will balance 72 parts of purple-blue. Posters submitted by artists are often analyzed in this way to enable the printer to reproduce them correctly.

By way of illustrating the application of this system to automobile finishes, a series of celluloid tubes were shown in the cabinet and illuminated by concealed lights. The first was a solid red of 5 value and 5 chroma. Next was a red of 5 value and 7 chroma. These are the extremes in value in which a car can be painted in red only. Combinations of reds on the same cylinders were then displayed to show that as the values increase; that is, as a red became more intense, the area that can be used diminishes. Combinations of red with red-purple and yellow-red were exhibited to show the extremes that can be used.

Opposite Colors Accentuate Each Other

Blue-green and red, opposite colors, is the most powerful combination that can be made, as each accentuates the other, because the opposite or complementary color is always more powerful than any neighboring color in value or chroma. The colors are limitless; some automobile companies say they have 600; they might as well have 6000, but all the effects can be produced with 20, asserted Mr. Allen, who said he had made 320 colors in 3 years with 14 pigments. The plan is to work down to simpler things and fewer colors and to know more about them. Then one can paint all the colors he wants. He then showed how stripes of strong color can be made to accentuate the adjacent less brilliant colors and harmonize with them.

Color dimensions or qualities as used in the Munsell system were defined concisely in response to a question put by Azel Ames as follows: Hue is the color, as red, yellow, green, blue, and purple. Value is the quantity of light that any color reflects, from white to black. This can be divided as desired into 10, 20, 40 or 60 parts or steps. Chroma is the intensity or relation of a color to its opposite color. At the Bureau of Standards, he said, is a beautiful instrument built by Dr. Priest with Mr. Munsell's assistance during the last 3 years, with which the amount of any color in any kind of material can be measured and a spectrum reading taken. It is a colorimeter that gives a spectrum for the selection of three primary colors and has two powerful magnesia lights that can be moved toward the center to give any desired strength.

W. G. Wall inquired if there is any simple way of measuring the colors on a car to tell the predominating color. Mr. Allen replied that this could be done with a magic lantern with ruled squares on it. By looking through the lantern the number of squares of each color could be counted. A more accurate way is to have the color design on a card and trace around the areas with a planimeter to establish the areas in square inches.

Summer and Winter Finishes May Differ

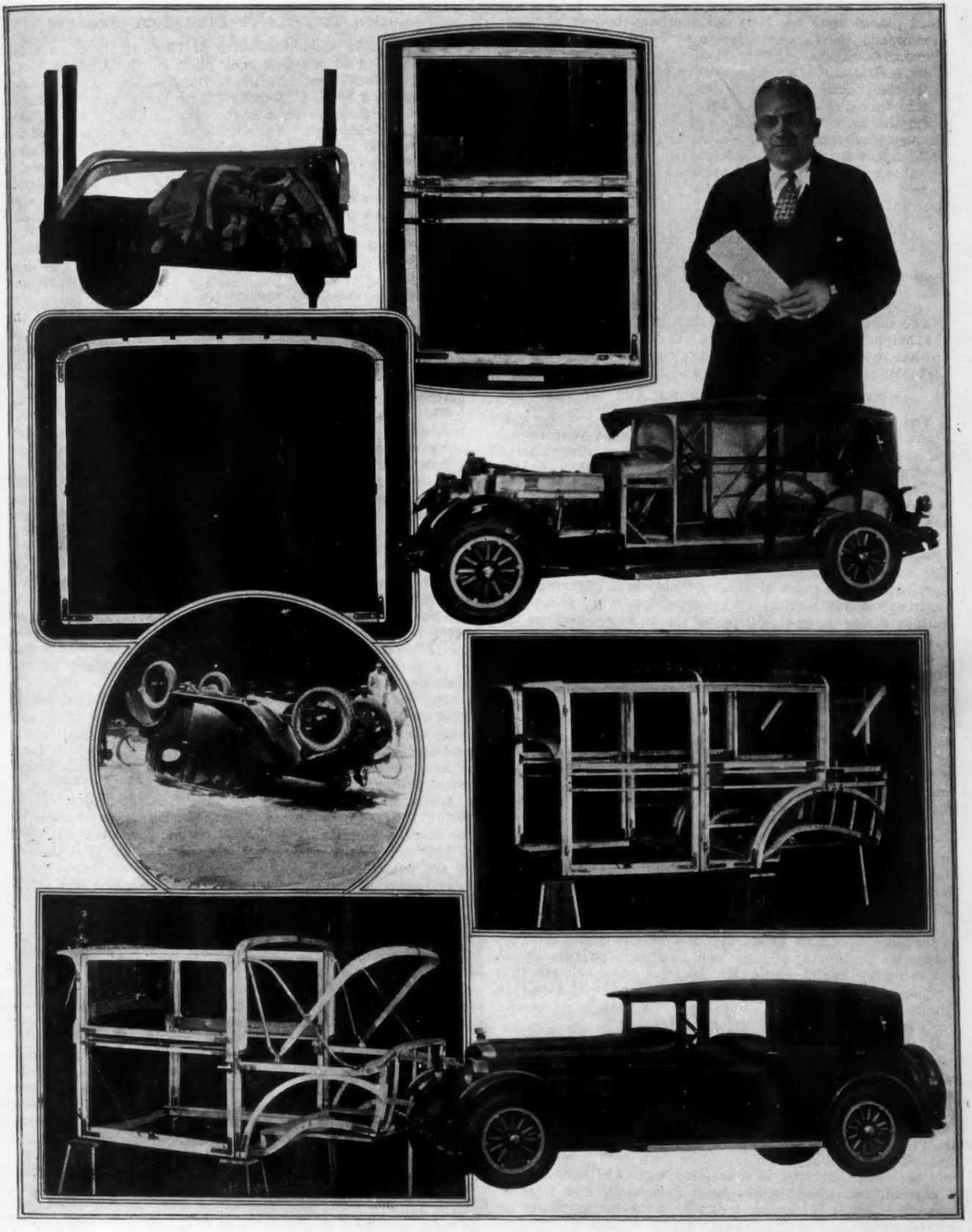
In response to another inquiry Mr. Allen said that this system is fully explained in a color notation and in 15 atlases published by the Munsell Color Co.

H. Ledyard Towle asked if it would be possible to make a small drawing of the side view of a car with the areas colored and place the drawing on a spinning wheel so as to check the colors. To this Mr. Allen answered that it would be necessary to transpose the areas into proportions on discs. Mr. Towle stated that the Munsell system seemed to him to offer a good check-up method but that sometimes when a system is not used one gets certain accidentals or psychological effects that are interesting and that in the automotive field there is a place for both the Munsell system and the variation of personality. Mr. Allen explained, however, that the matter of pleasing color-combinations is very exact and that a large percentage of people will prefer certain colors and areas in combination without knowing why they like them. It is therefore very important to use the proper colors. He thought that no doubt the time will come when the wealthy and fastidious will want cars in different colors for summer and winter because the background in winter is entirely different from that in summer. They would not want a bright red car when the ground is covered with snow but it might do against a strong greenish background.

Better Bodies Require Chassis Changes

Greater possibilities in body designing exist than ever before was the opinion expressed by R. H. Dietrich, in his paper on body design. He said that the demand for low cars, good proportion in design, harmony in exterior finish, and comfortable seating will be the governing factors in public buying. Simplicity will be one of the finer trends of the future. Length of the chassis plays an important part in getting good body-proportions, and it is about time that the chassis engineer give some consideration to the position of pedals and steering-wheel. When some years ago the steering-column was lowered and the pedals extended into the body to bring the body height down, the changes did not help the seating conditions but shortened the distance that the body designer had to work with, and now that a trend to short wheelbases has developed, the same seating comfort cannot be obtained unless the chassis engineer gives his aid. It has been necessary to extend the body far beyond the rear fender and make a big cut in the rear door to clear the rear-wheel housing, thus cramping the entrance to the rear compartment. By placing the steering-wheel closer to the dash, setting the pedals farther into the engine compartment and suitably altering their throw and distance of travel, better seating arrangements can be provided and the proportion and design of the chassis itself improved.

Some consideration should also be given to the striking clearance between the rear axle and the frame so that the car will not have the appearance of taking a nose dive during the nine-tenths of the time when it is not under full passenger-load. With spring deflection designed for full load, blame for the lack of comfortable riding-qualities has



STEPS IN THE CONSTRUCTION OF THE WEYMANN BODY

Structural Parts for One Complete Body Are Shown at the Upper Left; Herman Steinbrugge, Who Presented the Paper on the Weymann Body, at Upper Right; Steps in the Body Construction, a Finished Body and an Impromptu Test of the Strength of the Weymann Construction

been placed upon the body designer and builder and assertions made that the seats have a tendency to pitch the riders forward and that the cushion springs are not suitable. How, asked Mr. Dietrich, can these conditions be helped when the chassis springs are designed for full load and most of the time the car carries only from two to four persons? With the help of the chassis engineer in the items of rear springs and position of the steering-column and pedals, the builder can produce a vehicle that will have more comfortable riding-qualities and present a more pleasing appearance.

Adjustable front seats must be developed and placed on the market so that drivers of different stature can be made more comfortable. These seats should not only slide forward and back but should be made so that the angle of the seat cushion and back can be changed at the same time. On a long ride the driver would thus be able to change his position to relieve muscles stiffened by sitting in one position.

The high kick-up for the chassis at the rear determines the height and position of the rear-seat cushion springs, so that it is impossible to give the cushion and back a comfortable angle.

How Apparent Dimensions Are Altered

The appearance of a car as to height and length can be altered by the body builder by tricks learned years ago in the carriage-building trade, as by the use or elimination of molding, or so-called cheat lines. The double-belt molding will be replaced by a single molding run perhaps through the hood and all around the body or perhaps terminated at the base of the windshield, Mr. Dietrich believes. Lowness can also be expressed by a molding at the body sill, either continued through the body or ended at the wheel-housing. The wider the molding the lower and longer the entire design appears. Crown of the roof also is a governing factor in expressing lowness. A crown of 5 to 6 in., with proper contour across the roof, eliminates the bulky appearance that a heavy crowned roof sometimes has.

Size and proportion of the glass also have a place in expressing desired car-proportions. Proper location of the vision line with relation to cowl, hood and radiator and also the height of the door header play an important part. Lowness can be expressed by making the header rail 2¼ to 2½ in. deep, which does not cheat the entrance height, and by making the glass wider than it is high.

Appearance of the car from the rear is improved very much by dropping the rear corner of the roof to offset the rear height due to the springs when the car is not fully loaded.

Clear-vision posts can be designed that will not appear too light from the outside yet will give the minimum obstruction in the vision line. When the "blind spot" has been generally eliminated the cost of liability insurance will come down. Proper design of the windshield header will serve to eliminate the visor completely and remove the cumbersome appearance that now exists at the front.

Interior design, upholstery and hardware or furnishings are changing rapidly, said Mr. Dietrich, who believes that simplicity will be the governing factor and will result in eliminating vanity cases, since every woman now carries her own, and some other fittings.

It is very difficult to decide whether soft harmonious pastel colors or strong contrasting colors will prevail in exterior finish, but the speaker advised that in time of prosperity lively color-contrasts and extreme color-harmony be employed. However, shades that are suitable for one type of car may not be suited to a different style. Some colors are very costly and cannot be applied by the kind of labor that must be employed on low-price cars. With high-price cars the color harmony is considered when the body design is started, not when it has been completed, and a color drawing is made for every design to make certain that the coloring is adapted to the design. Pastel shades are coming into vogue and will be used more than ever because of their softness.

[1] See THE JOURNAL, February, 1925, p. 215 and January, 1927, p. 49.

Motion Pictures of Steel-Body Building

Two reels of motion pictures of the operations in steel-body building at the new body plant of the Hudson Motor Car Co., which went into production last June, were shown and described by V. P. Rumely. Both the Hudson and Essex composite bodies are built in the plant, which is 900 ft. long and four stories high. After presenting exterior views of the plant, the film showed the unloading of steel sheets upon electric rack-trucks that carry 10-ton loads and are hoisted on lifts. The whole bundle of sheets is rolled by the truck to the presses and stored as near them as possible. The contrast between this method and the old one of manual handling was shown.

Then came the rolling of the panel sheets to smooth them out and the operation of the power-tool making cuts in dies. The finishing of a fender die costing $10,000 was shown and the reel also showed a $40,000 press with which three men form 200 fenders in 1 hr. Next came the reinforcing of the fender edges with wire, the fenders coming out on conveyors, loading of the fenders in racks and the conveying of the racks by overhead trolley to the main plant for enameling. The racks were lifted in pairs. Next came a general view of a battery of presses extending the full 900 ft. of the building.

This was succeeded by a view of the stamping of cowls in a single operation, forming the quarter panels and trimming and perforating the edges. Sill operations in which a pair of left and right sills are formed at each stroke of the press came next and then the pressing of the doors and the blanking and perforating of the steel door-pillars. After this came the blanking-out of dashes, assembling of the dashes by spot welding and the assembling of the dash and cowl by bolting and spot welding.

Overhead conveyors carried the finished parts to the start of the body-assembling line along which the bodies travel on wheeled trucks on rails. After being assembled the bodies are sanded and inspected and then painted with an air-gun, after which comes the striping. Then the bodies are loaded on double-deck trailers 45 ft. in length, which carry 16 bodies at a load and haul them to the main car plant of the company.

The pictures also showed how pieces of unused sheet steel cut from the blanks in forming the panels, doors and other parts of the bodies are used for making small parts and also how scrap metal is baled in a press, in which form it sells for $5 more per ton as baled scrap than loose scrap-metal brings.

When the pictures had been run off, A. J. Scaife, of the White Motor Co., inquired what the present production of the plant is and Mr. Rumely said that it now has a capacity of between 800 and 1000 bodies per day because it is limited by the painting operation. The presses have a capacity of more than 1500 bodies per day of 9 hr. The plant was originally laid out for enameling instead of painting.

Principles of Flexible-Body Building

Running comment on the principles and methods followed in the building of Weymann flexible bodies as shown in a series of lantern slides was made by H. Steinbrugge, who after giving a list of nearly 40 European car builders who are now using Weymann bodies, stated that the patentee has factories operating in England, France, Italy, Belgium, and Austria. These produce small series of bodies for automobile companies and also build bodies for high-class custom trade, but more than 95 per cent of Weymann bodies are produced by licensees. A patent-holding company has been formed in the United States to issue licenses for the construction of these bodies and a manufacturing company has also been formed under the name of the Weymann American Body Co., which has leased the property formerly occupied by the National Motor Vehicle Corporation in Indianapolis.

The lantern slides and description were largely the same as were presented in papers[1] read at the 1925 Annual Meeting of the Society and the December, 1926, meeting of the Indiana Section.

The more important features of construction are that the wood frame-members are assembled in two parallelograms

with flexible joints made of cold-rolled steel held to the ends of the wood sticks by countersunk and riveted screws. These parallelograms are assembled on wooden horses with spacers between them to assure perpendicularity and are then covered first with canvas and finally with imitation leather. Two men said Mr. Steinbrugge, can easily cover a body in 2 days. The doors are very light and also flexible and are secured to the body by spring hinges and held closed by a special lock that allows relative movement between the door and door jamb. A sample of this lock was passed through the audience for examination.

To show how little lumber stock is required for these bodies, Mr. Steinbrugge showed a slide of a small hand-truck containing a very small load of finished frame members for a complete body and also one of a stock of lumber for 10 complete bodies stored in racks ready for assembling.

Although a body built in America for a large car weighs 550 lb. less than a conventional composite body of the same style, it has ample strength, as was made evident by two slides showing cars that had been overturned and were resting on the roofs. One reason for this strength of the light wooden members is that the uprights are not mortised or cut away.

Affords a Way of Lightening Cars

In opening discussion on the subject, W. G. Wall, of Indianapolis, said that for a number of years the industry has been talking about making cars lighter but that little has been done in this direction, as engines weigh as much as they did 15 years ago although they are developing greater horsepower, and the chassis weighs more. The flexible type of body offers a way of lightening the car and another advantage is that the seats are secured to the chassis so that the main portion of the body is merely a cover to afford protection against weather. He said that it looks as if all-steel bodies and composite bodies would have to be made lighter so that the chassis can be reduced in weight and engines made smaller.

In response to questions as to the kind of wood used, Mr. Steinbrugge said that ash is used commonly but each licensee uses any kind he desires, depending upon the class of body that is being built. The wood is not kiln-dried, as once the body is assembled it cannot warp. To a question as to what is used between the steel and wood at the joints to prevent squeaking, he said that generally nothing is used although sometimes a film of paper or piece of cloth is inserted but that wood in contact with steel does not squeak and most of the joints are very small. Although the body is flexible the movement is scarcely visible; the top may flex ¼ in. in normal action of the joints.

To close the spaces left when the spacers between the parallelograms used when assembling are removed, a rubber filler is used on the inside which lies flush with the door and on the outside a beading is formed that extends from the door to the body post. This beading is made of rubber covered with leather and the ends of the leather are glued together and nailed so that the rubber beading fills the gap. On the inside it is fastened to the door post and on the outside to the door. After the trimming is finished and the iron plate put in, the space between the door post and body post is only 4 mm. (approximately 1/6 in.) wide.

Weight Saving from 35 to 60 Per Cent

E. L. Bare, of the Murray Body Corporation, inquired whether any bodies for small cars have been built and what was the saving in weight. To this Mr. Steinbrugge said that the saving is more on a large car than on a small one and amounts to about 60 per cent of the weight of a conventional large body and from 35 to 40 per cent for cars of the size of the Ford and Chevrolet. The Stutz car, when fitted with a flexible body and with the lightest runabout springs substituted for the heavy springs, weighed complete 580 lb. less than formerly.

Asked by Mr. Bare how the tendency of the glass to break is counteracted, Mr. Steinbrugge stated that a clearance of about ¼ in. is left at the side of the glass to take care of the flexing of the body and that the window is suspended by silk cords which are used for raising and lowering it, as it was found that chains rattle.

A. S. Allen R. H. Dietrich

Two Authors Who Presented Papers at the Body Session

The question of the danger of headlights or other parts of vehicles poking through the sides of the body was disposed of by the statement that pointed objects such, for example, as the end of a shaft or thill of a wagon might go through but that the main structural beams are relied on to resist most impacts and that the artificial leather is very strong, as it has a closely-woven fabric which is much heavier than that used ordinarily and has a square weave so that it stretches the same amount in one direction as in the other. This is placed over canvas and horsehair filling. No wire netting whatever is used in the body, as it would prevent flexion of the frame and is difficult to secure to anything that is flexible.

Mr. Towle, commenting on Weymann bodies that he saw at the Paris automobile show finished in imitation crocodile leather, moire, silk, and other styles, stated that it started him thinking of the factor of surface finish. With steel bodies, he said, we have been accustomed to bright shiny finishes but perhaps we can apply pyroxylin or other materials to steel surfaces in some way to secure a soft dull finish totally unlike anything we have today.

THE BUSINESS SESSION

Reports of the Administrative Committees Submitted and Accepted

The Business Session convened in New York City on Jan. 13 during the Annual Dinner in order that the report of the tellers of election on the election of officers for 1927 might be submitted in accordance with constitutional provisions, but it was adjourned to Jan. 25, the first evening of the Annual Meeting. First Vice-President J. H. Hunt presided at the adjourned meeting owing to the unavoidable absence of President Litle.

The reports of the administrative committees of the Society were all presented in written form and accepted without discussion. These are given in full hereinafter for, in the words of Mr. Hunt, the members should read these reports carefully as the success of the Society depends upon the care with which the administrative committees and the other committees carry out the duties assigned to them.

Meetings Committee Report

Chairman L. C. Hill presented the following report of the activities of the Meetings Committee for the last administrative year:

> During 1926 six national meetings were held. In order of the attendance, they were Annual Meeting, Summer Meeting, Transportation and Service Meeting,

COMPARISON OF 1925 AND 1926 MEETINGS

Meeting	1925 No.	1925 Place	1926 No.	1926 Place
Annual Dinner	911	New York City	1,073	New York City
Annual Meeting	832	Detroit	942	Detroit
Carnival	909	Detroit	1,085	Detroit
Summer Meeting	714	White Sulphur Springs	787	French Lick Springs
Aeronautic Meeting	323	New York City	226	Philadelphia
Service Meeting[1]	292	Chicago	....	....
Service Engineering Meeting[1]	139	Chicago	....	....
Transportation Meeting	236	Philadelphia	....	....
Transportation and Service Meeting	....	....	407	Boston
Production Meeting	327	Cleveland	325	Chicago
Tractor Meeting[2]	150	Chicago	69	Chicago
Motorboat Meeting	69	New York City	....	....
Total Attendance	4,992		4,914	

[1] Held in conjunction with National Automobile Chamber of Commerce.
[2] Held in conjunction with American Society of Agricultural Engineers.

Production Meeting, Aeronautic Meeting, and Tractor Meeting.

The Annual Dinner and Carnival were held as usual. A comparison of these meetings is given in the following table. Although the total attendance for 1925 exceeds that for 1926, the fact that joint service meetings with the National Automobile Chamber of Commerce were not held in 1926 accounts for the difference.

The intent of the Meetings Committee has been to hold National meetings on all subjects warranting more discussion than can be given at one or two sessions at each Annual and Semi-Annual Meeting, varying the location of these meetings so as not to throw the burden of traveling on the same members in the same degree each year. It has recognized that the matters discussed should be of the greatest timely interest and that they should be presented so as to provide information of real value to engineers. It has appreciated that discussion may be of much greater value than the papers presented and it has therefore allocated the time of the sessions equally between the presentation of papers and the discussion.

With the keen interest in all phases of aeronautics and the very interesting outlook in this field of automotive engineering today, the Meetings Committee realizes that its decision to hold a National Aeronautic Meeting in 1925 was well taken. With two highly successful Aeronautic Meetings to its credit, it believes that this meeting is definitely recognized as an outstanding National event and that future meetings will stand second to only Annual and Semi-Annual Meetings.

Interest in transportation as evidenced at Boston during the Transportation and Service Meeting indicates that the interest in automotive transportation in the larger cities is sufficiently local to assure the success of such meetings even though they are not National in character.

The meetings attendance figures for 1926 indicate that the average number of meetings attended by a member, assuming no duplication in attendance records occurs which, of course, is not the case, is slightly less than 1. The Meetings Committee fully appreciates that many members do not attend any National meetings, either because of their location or interests, but it believes that the ratio of 1 meeting per member per year can be increased considerably. A member who depends on THE JOURNAL as the only means of keeping in touch with the industry is losing a great advantage. The purpose of the meetings is not only to disseminate information but to bring the automotive engineers together so that they can discuss their problems, both during and after the sessions, and extend their acquaintanceship among men with similar interests.

It should be borne in mind that the members presenting papers at the different sessions obtain very much more from the meetings than those who attend the sessions even though they take part in the discussion. To present problems or information in a logical manner is a great help in consolidating material and the discussion generally suggests possibilities that might not be indicated otherwise.

The Meetings Committee stands ready to pass on all papers submitted by members and will include those approved in the program of the first possible meeting. Programs for National meetings are completed at least 2 months in advance of the meetings and papers written with definite meetings in view should be submitted at least 3 months in advance owing to the time necessary for approving papers.

MEMBERSHIP COMMITTEE REPORT

The report of the Membership Committee, which was presented by its Chairman, H. L. Horning, was as follows:

In the last year the Society's membership has been increased so that on Dec. 31, 1926, the number of Members and Affiliate Member Representatives was 5763. This shows a gain of 344 over 5419 total membership reported at the 1926 Annual Meeting and also a greater increase than that of the previous year.

The Committee feels that the practice of dropping members who are not sufficiently interested in the Society to pay their dues, within the time provided by the Constitution and the By-Laws, is resulting in a strengthening of the membership. On Jan. 1, 1927, 78 per cent of the members had paid dues for the current fiscal year.

The present status of the Society's membership, as compared with that of 1925, is as follows:

	Dec. 31, 1925	Dec. 31, 1926
Members, including Service and Foreign Members	2,978	3,095
Associates	1,687	1,858
Juniors	453	503
Affiliates	109	110
Affiliate Representatives	192	197
	5,419	5,763
Enrolled Students	175	221
	5,594	5,984

The Membership Committee wishes to express its appreciation to the members who assisted it by sending in the names of prospective members on the postcards mailed to them from time to time. The Section Membership Committees are also to be complimented on their interest in enrolling new members.

The number of applications received by months is indicated in the following table:

	1925	1926
January	79	84
February	66	99
March	71	74
April	81	101
May	117	76
June	91	62
July	62	41
August	62	48
September	66	75
October	87	83
November	74	69
December	92	69
	948	881

PUBLICATION COMMITTEE REPORT

On behalf of the Publication Committee, its Chairman, Hon. E. P. Warner, submitted the following report dealing with this phase of the Society's activities:

Publishing issues of THE JOURNAL containing the largest total number of pages and the greatest number of text pages in the Society's history and getting the issues containing the news accounts of the Semi-Annual and the Aeronautic Meetings in the hands of the members as soon as or sooner than the trade periodicals containing the stories, are probably the outstanding features of the publication work of the Society for the year 1926. The total number of pages in the 12 issues was 3012, of which 1457½ were text, the corresponding figures for 1925 being 2734 and 1384½ respectively. The February issue with a total of 320 pages and 177½ pages of text was the largest number of THE JOURNAL ever published, and the December issue had the greatest number of text pages, 186¼. Papers and contributed articles to the number of 135 were published in 1926, as compared with 125 during the previous year. Details of the size of and the material published in THE JOURNAL for the last 2 years are presented in Table 1.

TABLE 1—COMPARATIVE DATA ON SIZE OF AND MATERIAL INCLUDED IN THE JOURNAL FOR 1925 AND 1926

	1925	1926
Total Pages	2734	3012
Text Pages	1384½	1457½
Percentage of Text Pages	50.8	48.4
National Meetings Papers Published	78	75
Section and Group Meetings Papers Published	39	55
Discussions Published Separately	42	35
Contributed Articles Published	8	5

From the viewpoints of care and thoroughness the editing of the material published each month in THE JOURNAL compares very favorably with, if indeed it does not surpass, the work done by the editorial departments of similar organizations. This policy results in the elimination of all superfluous material, both text and illustrations, and is also reflected in the comparatively small number of corrections that have to be made after publication. That the care taken in editing does not interfere with promptness in getting the papers into THE JOURNAL is evidenced by the fact that of the papers printed without discussion 59.5 per cent were published in the first issue after their presentation. Table 2 shows how promptly material was published in 1926. The delay in publishing papers and discussions in the same issue or separate discussions of papers is due to the submission of the edited transcript to the authors and discussers for correction before publication.

As has been the policy for the last few years illustrated news stories of Society and Sections meetings held the previous month appear in the Meetings of the Society department of THE JOURNAL each month. Special arrangements are made to get these reports into THE JOURNAL promptly after the different meetings, press rate telegrams and the Air Mail Service being employed. The June issue containing the news story of the Semi-Annual Meeting went to press 4 days after the close of the meeting, while the September number which carried a similar account of the Aeronautic Meeting was ready for the press in about 17 hr. after the last copy was received and was mailed to the members on the fourth day after the close of the meeting, notwithstanding the fact that a Saturday half-holiday, a Sunday and Labor Day took up over 60 per cent of the intervening time. In both instances the members received copies of THE JOURNAL as soon as they did the trade periodicals containing the accounts of the meetings.

The Semi-Annual Index which had formerly been printed as an integral part of the June and December numbers of THE JOURNAL was omitted from the June issue and was printed in separate pamphlet form as Section 2 of the July issue. This effected a saving of 2 days in the time of mailing the June number and made possible the feat mentioned in the preceding paragraph. The Index was also omitted from the December number, the gain in the time of mailing in this instance being at least 3 and probably 4 days.

Part II of the 1924 TRANSACTIONS was issued on April 15 and Part I of the 1925 TRANSACTIONS followed on Oct. 26. The former of these volumes consisted of 724 pp. and contained 30 papers; the corresponding figures for the latter are 568 and 27 respectively. Work on Part II of the 1925 TRANSACTIONS is now being carried on, both in the office of the Publication Department and at the printing plant. This volume, which will probably be mailed to the members early in the spring, will contain 43 papers and consist of approximately 928 pp. At present the Publication Committee is considering the list of papers to be included in Part I of the 1926 TRANSACTIONS. The general procedure in

TABLE 2—TIME ELAPSING BETWEEN PRESENTATION AND PUBLICATION OF PAPERS

	Papers		Discussions Printed Separately		
	No Discussion	With Discussion	Separate Discussion	After Presentation	After Publication
Total	73	39	18	35	35
First Available Issue	38	..	16	..	..
Months Later					
1	8	..	2	..	..
2	8	1	..	..	2
3	3	6	..	3	5
4	6	5	..	3	5
5	8	17	..	4	8
6	..	6	..	13	6
7	..	1	..	1	5
8	..	..	..	6	2
9	..	1	..	3	2
10	..	..	..	2	..
11	1	1	..	..	..
12	1	..	..	..	..
13	..	..	..	..	..
14	..	..	..	..	..
15	..	1	..	..	..

approving material for the TRANSACTIONS continues as heretofore, the Committee's attempt being to select those papers likely to be of at least semi-permanent reference value. The percentage of total available material selected for the TRANSACTIONS continues to run about 60.

As in the past, reprints have been furnished to authors and interested organizations. In the year 1926, 35 such reprints were handled by the Publication Department.

On Dec. 31, 1926, 26 papers and discussions had been approved for publication and were awaiting the attention of the Publication Department, 8 were being considered for publication and 7 were in the hands of authors and discussers for the correction of their remarks; as compared with 25, 4 and 9 respectively at the close of 1925.

RESEARCH COMMITTEE REPORT

Dr. H. C. Dickinson, chairman of the Research Committee, outlined the work of the Committee for the last administrative year in the following report:

Since the last Annual Meeting of the Society some changes have taken place in the organization of the Research Department. The appointment of C. B. Veal as Research Manager to succeed Otto M. Burkhardt, who resigned during the summer, was the occasion for a discussion by the Research Committee, at a meeting last October, of the relations of the Research Department to the Society, to college and university research groups and to industrial laboratories and the industry as such. It was recommended that the Department establish and maintain as close contacts as possible with university laboratories for the encouragement of research projects which are of special importance to the automotive industry and that it endeavor to secure cooperation in research problems between the various industrial laboratories and between allied industries such as the petroleum industry, the tire industry and others, and the automotive industry.

As the Research Committee meets mainly for deliberations concerning active research work being carried on by its members and others in various places, a report is necessarily for the most part a summary of results on these various projects as collated by the Research Department, and an outline of the work of the Department itself.

FUEL-RESEARCH

Among the projects completed during the past year in the fuel-research program is that of crankcase-oil contamination. This investigation, which extended over two seasons, was designed to reveal the general condition of contaminated oil in crankcases of automobiles operated throughout the Country. A report of this survey was published in the December, 1926, issue of THE JOURNAL, under the title: Causes of Wear and Corrosion in Engines, by Otto M. Burkhardt.

The subject of detonation has been approached from four different angles, all of which are covered by papers to be delivered at the Annual Meeting, at the Detonation Session, on the morning of Jan. 26, and at the Research Session. Considering the lack of a generally accepted method for measuring the antidetonating qualities of gasoline as a handicap to systematic research in this field, the Cooperative Fuel-Research Steering Committee at its April 23, 1926, meeting incorporated in its program a survey of the methods now in general use with a view to the ultimate general adoption of some one method. Plans were also laid for the collection of a bibliography of the significant published material on the subject. H. K. Cummings' paper deals with these two items.

At the same meeting a recommendation was made that a symposium on the engineering and economic aspects of detonation be part of the next Annual Meeting of the Society. At the June 2, 1926, meeting of the Research Committee, the Chairman was asked to appoint a committee to supervise the preparation of a summary report on the work done so far to determine the effects of detonation, which would be a part of such symposium. The following committee was appointed: Thomas Midgley, Jr., chairman; Dr. T. G. Delbridge; S. W. Sparrow; and R. E. Wilson. The symposium is part of the Detonation Session; the report of the committee will be given at the Research Session.

The fourth detonation project is the survey of the antiknock characteristics of gasolines now on the market. As a preliminary to a broad inclusive survey, a more restricted investigation is being carried out, in the course of which about 12 samples illustrating the products of 6 oil companies are being analyzed.

Lines of research on which the experimental program so far laid down has been completed are the investigation of the relation between fuel-volatility and engine-starting characteristics and the development of laboratory methods for the measurement of fuel-volatility. Broadly speaking, the engine-starting investigation has consisted of tests made with four special fuels designed to bring out the effect of a fuel's 5, 10 and 20-per cent points on its starting-characteristics. Both the glass-bomb and the continuous air-distillation methods of measuring gasoline-volatility have been the subject of study with the object of evaluating the factors governing reproducibility of results and so drawing up instructions that the procedure may be available for use by other laboratories. Progress in these two departments of the cooperative fuel-research was reported in two papers delivered at the Summer Meeting; accomplishment since that time is covered in a paper by C. S. Cragoe and J. O. Eisinger at the Research Session of the Annual Meeting.

A project that will occupy a large part of the immediate future program is the study of engine performance in the warming-up period to determine the effect of fuel characteristics, in particular the intermediate portion of the distillation range, on this period of operation. Some study of engine characteristics may also be made in this connection.

HEADLIGHTING

The headlighting, like the fuel, research has been carried on cooperatively, the organization joining the Society in this activity being the Illuminating Engineering Society. Two aspects of the research were briefly reviewed under Automotive Research, in the September, 1926, issue of THE JOURNAL. Here were summarized investigations carried on by a number of research workers on certain visual fundamentals involved in headlighting and some concrete practical considerations affecting head-lamp construction.

However, the major portion of the efforts in the headlighting field have been devoted toward enlisting the cooperation of motor-car and lamp manufacturers in a fundamental study of lighting distributions. A suitable instrument for such a study, a four-headlamp test equipment, has been developed, its features have been presented to those interested, and sets have been prepared for those who desired to purchase them. To keep the Society informed on the methods of this research and to give purchasers of the equipment some idea of the results that can be obtained with it, two articles have been published in THE JOURNAL under Automotive Research, one in August and one in October. According to plans now under consideration, a demonstration will be held in the spring at which those who have experimented with the equipment will show what they have arrived at as ideal driving illumination. The Joint Steering Committee on Headlight Research of the Illuminating Engineering Society and this Society at a meeting in January discussed suggestions for the conduct of such a demonstration submitted to it by the Head-

light Subcommittee on Distributions, of which J. H. Hunt is chairman.

By this method of research it is hoped to stimulate independent thinking on the fundamental questions involved in automobile headlighting and to gain for any proposed solution of the problem the active support of those who can most effectively secure its common adoption, the manufacturers.

RIDING-QUALITIES

Under this comprehensive heading three fields of research are included: a study of instruments for the measurement of impacts and vibrations felt by an automobile passenger; of those parts of a motor-car that add to or subtract from the impacts and vibrations and of persons from a psychological point of view to determine what accelerations are unbearable, unpleasant or unobjectionable. Dr. Benjamin Liebowitz has cooperated with the Research Committee in contributing to two of these fields; in the November, 1926, issue of THE JOURNAL, under Automotive Research, is published his analysis of the effect of gap-clearance in contact-accelerometers; in the December, 1926, issue, also under Automotive Research, a report prepared by Dr. Liebowitz as a representative of the Society to the Special Research Committee on Mechanical Springs of the American Society of Mechanical Engineers.

Tentative plans are now under consideration for some investigation into the third or psychological aspect of the problem. An apparatus for such a study, a vibrating chair, has been developed and experimented with to some extent at the Bureau of Standards. Prof. E. H. Lockwood, a member of the Riding-Qualities Subcommittee, with Prof. L. C. Lichty, both of Yale University, is considering the use of this or similar equipment at the Sheffield Scientific School for an investigation of the susceptibility of the average person to vibrations of various amplitudes and periods.

HIGHWAYS

The Society has continued its participation in the cooperative study of motor-truck impacts, in which the Rubber Association of America and the Bureau of Public Roads are our co-workers. In the last 6 months the research has included cutting down and testing cushion and solid tires. Among the tests conducted were those of 36 x 5-in. dual cushion tires and 36 x 4-in. dual high profile tires on a 2-ton truck and 36 x 7-in. and 36 x 8-in. dual cushion tires and 36 x 5-in. and 36 x 7-in. dual high profile tires on a 3-ton truck. Also on the program was the testing of a combination dual tire-equipment for a rear truck-wheel which includes a 36 x 6-in. pneumatic tire and a 36 x 4-in. high-profile solid tire on a 2-ton truck.

The experimental work scheduled for the year 1926 has been brought to a conclusion and the data incorporating the results put into form for publication which, it is expected, will be made in the near future. All the data that have been developed by this project since its initiation are now being used in the interpretation of results of tests being made on road sections selected as typical of various highway conditions.

Information developed by this project is incorporated in papers delivered before this Society and other bodies. The paper read at the Transportation and Service Meeting, entitled the Motor-Truck Tire in Its Relation to the Vehicle and to the Road, by James A. Buchanan utilized to some extent the data developed by this research in the past.

ACTIVITIES IN RESEARCH DEPARTMENT

The Research Department attends to the executive details connected with carrying out the plans of the Research Committee. In addition to performing these functions for the projects treated above, the Research Manager is active on a number of matters not covered in detail. For instance, he is a point of contact between the Society and research departments of universities and other scientific institutions.

In this connection, as part of the plan for carrying out its purpose to act as a "clearing-house" for automotive technical information and research matters, the Department is making every effort to keep in touch with the activities of all related laboratories whether public, institutional, individual, or private covering personnel, equipment and work in progress, to the end that the greatest cooperative service may be rendered to the industry in the collection and dissemination of data.

The Research Department has also maintained its information service, furnishing bibliographies, lists of manufacturers of automotive devices and locating in automotive literature data on many and varying subjects brought up by an ever-increasing number of inquirers. These questions are also becoming steadily more technical in nature, requiring more thorough consideration and more extensive search for the data required. As a very conservative estimate, over 50 per cent of the entire work of the Department is devoted to the rendering of this information service, the facilities for which are continually available to other departments of the Society as well as to members and more or less the public in general.

So that such information may be readily at hand and kept uptodate, the Research Department reads and indexes about 75 technical and trade publications, and maintains a technical information file of pamphlets and clippings of especial value. A small and highly specialized library is also under the charge of the Research Department. This contains copies of the magazines referred to above for the current year, bound volumes of five selected publications and books on automotive engineering and allied topics. Thirty-five books have been added to the library in the last year.

The Research Department also furnishes each month for THE JOURNAL an article for the Automotive Research section, as well as 10 columns of Notes and Reviews. The latter consists of abstracts of reviews of current books or articles thought to be of special interest in the automotive engineering field, about 30 separate items being included in each month's contribution.

SECTIONS COMMITTEE REPORT

The activities of the Sections Committee were reported upon by J. H. Hunt, its Chairman, as follows:

During 1926 the Sections have been greatly strengthened by having a larger percentage of the Society members join them. The membership figures for the Sections on Jan. 1, 1926, and Jan. 1, 1927, are given in the following table.

COMPARISON OF SECTION MEMBERSHIP AS OF JAN. 1

Section	Membership 1926	Membership 1927	Increase, Per Cent
Northern California	37	64	73
Southern California	49	73	49
Metropolitan	507	679	34
Buffalo	83	100	20
Chicago	229	258	13
Indiana	84	94	12
Detroit	629	683	9
Cleveland	219	232	6
Milwaukee	78	83	6
Pennsylvania	176	185	5
Dayton	58	52	10[a]
New England	112	104	7[a]
Washington	51	45	12[a]
Minneapolis (Inactive)	..	..	..
Total Section Membership	2,312	2,651	15
Total Society Membership	5,419	5,763	6

[a] Decrease.

In 1925 the need for revising the Section Constitution, By-Laws and Rules was recognized, the Constitution then in use being practically obsolete. After considerable study a revised Constitution was prepared

during 1926 by the Sections Committee and submitted to each Section for comment and approval. With slight revisions it was subsequently approved by all the Sections and by the Council.

Owing to the interest in Student Groups at engineering colleges, a Subcommittee was appointed consisting of F. F. Chandler, R. E. Plimpton and John Younger, to study the desirability of encouraging the formation of such groups. The Subcommittee has made a careful study of conditions in several colleges and in other engineering societies fostering student activities and its report, which favors the organization of Student Groups where conditions indicate a real interest in automotive matters, will be submitted for action at the Sections Committee Meeting on Jan. 26. This Subcommittee also reviewed the proposed charter of the Ohio State University Student Group and suggested certain changes that were incorporated in it. In the revised form it will serve as a model for Future Student Group Charters.

In further carrying out the financial policy previously adopted and in operation for the Sections, the minimum bank balance allowance for each Section has been established, based on the cost of holding a meeting, or a given percentage of the annual budget, so that the Sections can always be reimbursed upon proper presentation of monthly expense statements and so have at all times sufficient funds to carry on their regular activities.

Standards Committee Report

The report of the Standards Committee, which was submitted by its Chairman, F. A. Whitten, was as follows:

The Standards Committee was organized in 1926 practically the same as last year with regard to the number of Divisions, with the addition of a Production Division. The 16 members of this Division were selected from among the men who are actively engaged in production work in the automotive plants.

The principal subjects assigned to the Production Division pertain to standardization of machine-tools, fixtures and other production equipment and their component parts. The principal work now in progress is the recommendation of a series of grinding-wheels commonly used in automotive work, selected on the basis of size, shape and grade and the general purposes for which they are used. The Division also acts on reports submitted to the Society by Sectional Committees functioning under the procedure of the American Engineering Standards Committee. The Division has already approved such a report relating to T-Slots, Their Bolts and Nuts and now has under consideration a tentative report on Tool Holders and Tool Post Openings.

MEETINGS AND REPORTS

Since the Semi-Annual Meeting in June meetings have been held by 11 Divisions and 8 Subdivisions. A large amount of the work before the Standards Committee has been carried forward by correspondence.

The recommendations of 11 Divisions of the Standards Committee, formulated since the meeting of the Society last June, include 37 subjects, some of them new ones, some revisions of present standards and a few cancellations. The complete reports of these recommendations are printed in the January, 1927, issue of THE JOURNAL.

S.A.E. HANDBOOK

The second edition of the S.A.E. HANDBOOK in bound form was issued in September, 1926, and was similar to the first edition sent out in March of last year with the exception that Section N, which includes the Index, Standards Committee personnel, Standards Committee Regulations, a brief description of "American Standards" as issued under the procedure of the American Engineering Standards Committee, and the Index to Advertisers, was printed on colored paper instead of white.

The decision to include in the advertising section of the S.A.E. HANDBOOK a general listing of manufacturers who certify that their products conform to S.A.E. Specifications was approved by the Council since publishing the September issue of the S.A.E. HANDBOOK. The Index, personnel and similar references in the Advertising Section will be placed in the text section of the S.A.E. HANDBOOK so as to have only the classified List of Manufacturers and the Index to Advertisers in the advertising section. The compilation of this listing of manufacturers is now progressing rapidly.

SECTIONAL COMMITTEES

The Society is a sponsor for the following Sectional Committees organized and functioning under the rules of procedure of the American Engineering Standards Committee:

(1) Aeronautic Safety Code
(2) Ball Bearings
(3) Bolt, Nut and Rivet Proportions
(4) Numbering of Steel
(5) Motor-Vehicle Lighting Specifications
(6) Pins and Washers
(7) Screw Threads
(8) Small Tools and Machine-Tool Elements
(9) Transmission Chains and Sprockets
(10) Wire and Sheet Metal Gages

It is also represented on the following Sectional Committees:

(1) Automobile Brakes and Brake Testing
(2) Code on Colors for Traffic Signals
(3) Drawings and Drafting Room Practice
(4) Gears
(5) Insulated Wire and Cable
(6) Machine-Tool Safety Code
(7) Plain Limit Gages for General Engineering Work
(8) Scientific and Engineering Symbols and Abbreviations
(9) Use, Care and Protection of Abrasive Wheels
(10) Specifications for Zinc Coating of Iron and Steel

The Society is also directly represented on more than a score of Committees of other organizations actively engaged in investigating important topics. Some of these projects are of a general nature affecting the broader interests of the Society while others relate more specifically to standardization activities.

SPECIAL COMMITTEES

With the growth of membership in the Society representative of motor-vehicle fleet-operation and maintenance interests, the Operation and Maintenance Committee has been organized to develop phases of the Society's work relating to this group in the automotive industries. Although the organization and work of the Committee has been done by the Standards Department, it is a general committee of the Society and not a standardizing committee. Its work bears on standardization, research, publications, sections activities, meetings, membership, and cooperation with other organizations such as the National Automobile Chamber of Commerce, the American Electric Railway Association and others.

The Production Advisory Committee was similarly organized more recently to foster the general work of the Society that bears more particularly on the interests of the production men in the industry. It was also organized and has been functioning with the assistance

of the Standards Department but is not a standardizing committee although it has a close relation to the Production Division of the Standards Committee. Its field of activities will be the same for the production interests as that of the Operation and Maintenance Committee is for the operating interests.

INTERNATIONAL STANDARDIZATION

Following the Third International Conference of Standardizing Bodies that was held in New York City last April and referred to in the Standards Committee Report submitted by the Chairman at the June, 1926, meeting of the Society, another meeting was held in September in London at which it was agreed that the several countries participating would delay decisive action for a year to give the American representatives opportunity to continue their study of this proposition before an international organization was set up.

TREASURER'S REPORT

Treasurer C. B. Whittelsey, in presenting copies of detail figures, made the following comments:

The last fiscal year of the Society ended Sept. 30, 1926. The figures for the year show that our gross income was $360,638.15, or an increase of $55,197.39 over the gross income of the previous fiscal year. The total expenses were $338,523.26, an increase of $33,488.55 over the previous year. The net unexpended income was $22,114.89, or an increase of $21,708.84 over 1925.

The Society owns securities representing a cost-value of $185,279.82, which is an increase of $39,404.69 over the previous year. These securities are held in custody by the Chemical National Bank of New York as funds to be drawn upon as emergencies or necessities arise.

It is very gratifying to note the increased membership in the Society and particularly in the Sections; also the increase in the percentage of members who pay their dues more promptly. Considerable saving would be made if all members would pay more promptly.

Advertising sales in THE JOURNAL have increased $36,514.08 over 1925, and in addition $13,500.00 of advertising was sold in the S.A.E. HANDBOOK. This has more than paid for the production of the entire book for the year, which has previously been an expense.

The budget for 1927 has been increased in proportion to the hoped-for growth of the Society. The income, which is estimated to be $378,400.00, will be guarded with extreme care and conservatism for the welfare and best interests of the Society.

The report of the Standards Committee was submitted by Chairman Whitten and approved without discussion.

A. J. Scaife, chairman of the Constitution Committee, read a comprehensive statement with regard to the status of the amendment to the Constitution with respect to making the Second Vice-Presidencies more representative of the various phases of automotive engineering, as proposed at the last Semi-Annual Meeting by J. F. Winchester. His amendment was withdrawn because the members of the Constitution Committee and some of the members of the Council felt that the matter should be discussed generally before any changes were made.

As the rsult of further discussion, propositions with reference to the Vice-Presidencies were submitted by F. F. Chandler, H. M. Crane and C. M. Manly, the propositions being read in full by Mr. Scaife, together with some information with regard to the changes proposed. No definite action was taken, the Council desiring to have the amendments also discussed by the Sections Committee. A complete outline of the changes will be printed in an early issue of THE JOURNAL.

Mr. Scaife outlined also the proposal of the Constitution Committee with reference to Section C46 of the Constitution reading:

> C 46 The annual Nominating Committee of the Society shall consist of one Member of the Society to be elected from and by each Section of the Society prior to the Semi-Annual Meeting; and three Members of the Society who shall be elected at the business session of the Semi-Annual Meeting preceding the Annual Meeting at which officers are to be elected; no two or said three Members shall reside in the same Section district.

which was to be amended to read "Annual Meeting" in each case to make it possible for the Nominating Committee to have a longer time in which to select the nominees. Mr. Scaife moved that this amendment be considered, the motion being seconded. In accordance with the Constitution of the Society the proposed amendment will be published in THE JOURNAL and a vote on the question taken at the Business Session at the Semi-Annual Meeting.

Upon the adjournment of the Business Session, F. F. Chandler introduced H. L. Cannell, chairman of the first student group of the Society, the Ohio State University Student Group. Mr. Cannell stated that the members of his Student Group had had an opportunity to hear Mr. Hunt at a recent meeting, and the members were highly appreciative of the good advice and knowledge they had received. The Ohio State University Student Group had decided, therefore, to make Mr. Hunt an honorary member, and Mr. Cannell therefore took the opportunity to present Mr. Hunt with a memento of their good wishes and appreciation, in the form of a paper weight, bearing the emblem of the Ohio State University Student Group, and to bestow on Mr. Hunt the title of Honorary Member.

COMPARATIVE BALANCE SHEET AS OF DEC. 31, 1926, AND DEC. 31, 1925

Assets	1926	1925	Increase	Decrease
Cash	$39,417.47	$27,927.06	$11,490.41	—
Accounts Receivable	24,416.24	39,128.03	—	$14,711.79
Securities	185,279.82	145,875.13	39,404.69	—
Accrued Interest on Securities	2,422.16	1,638.05	784.11	—
Inventories	1,129.25	9,666.38	—	8,537.13
Furniture and Fixtures	2,877.03	5,917.61	—	3,040.58
Items Paid in Advance, Charges Deferred	6,423.09	8,334.36	—	1,911.27
TOTAL ASSETS	$261,965.06	$238,486.62	$23,478.44	—
Liabilities				
Accounts Payable	$1,710.00	$7,507.61	—	$5,797.61
Accrued Commission	925.71	306.36	$619.35	—
Dues and Miscellaneous Items Received in Advance	63,388.81	61,590.17	1,798.64	—
Reserves Set Aside for Anticipated Expenses	11,654.61	7,927.94	3,726.67	—
General Reserve	174,801.15	162,360.33	12,440.82	—
Net Unexpended Income	9,484.78	1,205.79[a]	10,690.57	—
TOTAL LIABILITIES AND RESERVES	$261,965.06	$238,486.62	$23,478.44	—

[a] Deficit.

WORLD'S BEAUTIES LOOKED DOWN ON

Sir Alan Cobham, L. D. Gardner and Raycroft Walsh Recount Airplane Flights

Sir Alan Cobham kept nearly 400 members, guests and many ladies who accompanied them interested and vastly amused until a late hour at the General Session on the first night of the Annual Meeting by the graphic and humorous narration of his experiences on his airplane flights from London to Cape Town, London to Australia, and numerous other "taxi trips" in Europe. He was the star attraction, but of almost equal interest were the accounts given by Lester D. Gardner of his own flights by commercial air-lines in Europe, Western Asia and Northern Africa, and Major Raycroft Walsh's description and pictures of the airplane "courtesy" expedition through Central America by the United States Army Air Service.

All three talks were generously illustrated with lantern slides, the more spectacular and beautiful of which were those of the Victoria Falls on the Zambesi River in Africa, Mount Everest in the Himalaya Mountains, the Pyramids and Sphinx in Egypt and the volcanoes in Central America.

Most of his flights, said Sir Alan, were made to survey the possibilities of commercial air-lines and fire the imagination of the public to induce the people to view the beauties of nature from the air. Before taking his long flights he "used to do taxi flights" and toured Europe when no landing-fields were available in many places. He took the audience by picture and running comment on a 12,000-mile tour that he made with an American citizen from London, across the Continent, 480 miles across the Mediterranean, through Egypt, Palestine, Persia, and back.

To match a story previously told by Major Walsh, he declared that there are no such things as holes or pockets in the air but that the sudden drop of an airplane is due to descending air currents coming off of high mountains or coast lines and recounted how, when he was once skirting along a precipitous coast, he was caught by such a wind and the airplane dropped so fast that it fell away under the passengers and baggage so that they rose and stuck to the roof of the cabin.

His three longest survey flights were to Cape Town, South Africa, and return; to Australia and back, and to Rangoon, Burma, and back. Two of these were made with the same airplane and the same single engine. Now, he said, one can go by airplane from London to India in 9 days instead of 3 weeks; near the Pyramids is a terminus of an air-line to India, and airplanes now fly regularly down the Persian Gulf, where the surface of the adjacent land looks like a dead world.

Pictures were shown of his flight to the Himalayas 3 years ago when he got within 40 miles of Mount Everest and after reaching an altitude of 17,000 ft. had to turn back because of clouds rising below which would have enveloped the machine, as it could rise no higher.

On the Australian trip the success of his method of arousing interest became evident at Melbourne, where a vast throng of people was gathered to await his arrival and so crowded around the airplane that three elephants were used to keep them back.

Speaking of the Cape Town flight, Sir Alan said that one stretch of 3000 miles was over continuous dense tropical jungle. One of the many pictures shown was an aerial view of a great dam on the Nile in Egypt built to impound water for growing cotton. In commenting on the commercial utility of photography from the air, the speaker mentioned the convenience of such a birds-eye view of an industrial development for discussion of plans by a board of directors and said that, like the London *Times*, which is printed for those who cannot think, and the London *Mirror*, which is printed for those who cannot read, aerial photography is for those who can neither read maps nor think.

A number of views of the Victoria Falls were thrown on the screen and Sir Alan told how, while flying along the face of the 450-ft. drop within 20 ft. of the brink, the engine began to sputter because of water from the mist that had got into it. He wasted no time in getting out of there, he said, but returned after the engine resumed its regular functioning.

Flights on Europe's Airways

Mr. Gardner, publisher of *Aviation*, told of the delights of air travel in respect of beauty of the landscape from the air. He showed many pictures of European cities and public buildings which present an entirely different aspect from above than from the ground and said that architects in the future will have to design buildings with this in mind. The great Milan Cathedral in Italy is the only one ever built that looks more beautiful from above than from on the ground.

Major Raycroft Walsh

Sir Alan Cobham

Lester D. Gardner

The Three Attractions at the Airplane Session

Especially interesting to those concerned with aeronautics and aviation were slides of the Autogyro and the Petrodactyl in flight at Croydon, England, and the interior of the cabins of a number of the English, French, German, and Dutch airplanes operated on the commercial air-lines. One of these carries 20 passengers, is driven by three engines and has high-backed comfortable wicker chairs. Mr. Gardner said that the Croydon airport is now being entirely remodeled and the old wartime buildings replaced. He showed views of the airport near Paris which is used by six international air-lines. Other particularly interesting pictures were of Moscow, where the absence of automobiles was striking; Ypres in 1918 and last year after the city had been almost completely resurrected from the ruins of the War; Holland, with its dykes, windmills and canals; Gibraltar; the Sultan's palace in Casablanca, Morocco; the Atlas Mountains on the North African coast; the Alps, with their glaciers from an altitude of about 10,000 ft.; the walled city of Carcassonne, and the view of the Swiss Alps on a 20-min. flight that Mr. Gardner pronounced the most beautiful in all of Europe.

Airplane Courtesy Trip in Central America

Flying conditions in Central America were described entertainingly by Major Walsh, of the McGraw-Hill Co., who accompanied the American Army fliers on the "courtesy" trip that was the predecessor of the present "good-will" tour on which amphibian airplanes are being used. Tropical jungles that looked from a great height like rubble-strewn earth, the deep craters of volcanoes near Managua, Nicaragua; San Salvador and Guatemala City, capital cities of the republics of the same names; the landing-field at Managua, where the propellers stirred up great clouds of volcanic dust; and the serpentine railroad from Fonseca Bay to San Salvador were among the many pictures shown.

Major Walsh's account of the friendly attitude of the officials and populace of the different countries, especially in Panama, was of interest in view of recent developments in Nicaragua, but he said that the expedition did not enter Mexico but turned back in the northern part of Guatemala. There the atmosphere is extremely clear, in contrast with the moist air of the more southern countries.

QUALITY-MATERIAL PRODUCTION

Status of Cast-Iron Products and That of Chromium Plating Analyzed

Important criticism and valuable data relating to present and possible future practices in regard to cast iron and to chromium plating were among the outstanding features of the First Production Session that was held on the morning of Jan. 26. The present status of the production of cast iron with special relation to its quality was presented in great detail and suggestions were made regarding possible improvement of this extremely important material. The corrosion-resisting quality of chromium, the extension of chromium plating to wearing parts such as piston-pins, the use of chromium plating in place of nickel plating together with the ability of the former to withstand corrosion and rust, the chromium plating of automotive trimmings such as radiator shells, the successful plating of gages and taps with chromium, and the resultant increase in the length of life of these parts were all made the subjects of extensive comment. In the absence of Paul H. Geyser, of the Yellow Truck & Coach Mfg. Co., Chicago, Fred A. Cornell, of the C. G. Spring & Bumper Co., Detroit, officiated as chairman.

The first paper, entitled Cast Iron in Its Relation to the Automotive Industry, was presented by E. J. Lowry, of Hickman Williams & Co., Chicago, and was illustrated with interesting lantern-slides showing the photomicrographs of the structure of cast iron and charts. The second paper, on Chromium Plating, by W. N. Phillips, of the General Motors Corporation, was also illustrated by interesting photographs taken in various automotive plants. Both papers are printed elsewhere in this issue of The Journal. The discussion following their presentation was elicited by a much larger number of question cards than is usual, the answers constituting additions to the papers and comprising much valuable information.

In reply to the question whether expansion of cast iron is necessarily undesirable, Mr. Lowry said that it is undesirable unless in connection with two materials that expand at equal rates. He brought out also that in comparing test-pieces of high and low combined-carbon content, the quality is influenced more by the silicon present than by the combined carbon. He said that combined carbon has no real basic function, although of course it has a certain influence. In reply to the question whether cast iron can be treated so that its "growth" will be reduced, he stated that growth does not seem to be a function of the analysis that a cast iron may have.

Written discussion was presented by Arnold Lenz of the Saginaw Products Co., Saginaw, Mich., who stated that only a very short time ago, it would have been disastrous to take some of the cylinder-block or cylinder-head castings out of the sand while at a bright-red heat. Today, under modern manufacturing-methods, this procedure has become the rule rather than the exception and this is done with a lower percentage of cracked and warped castings than was ever true before. Incidentally, he said also that this new quality of iron, which leaves the iron practically unaffected under severe temperature-changes, has also practically eliminated the danger of cracks in the finished engine and that this has been accomplished with practically no change in the analysis.

E. M. Baker

E. J. Lowry

W. N. Phillips

F. A. Cornell

A Quartet of Prominent Attendants at the First Production Session

Professor Baker, of the University of Michigan, Took a Prominent Part in the Discussion of the Paper on Chromium-Plating. Messrs. Lowry and Phillips Were the Authors of the Papers Presented and Mr. Cornell Presided

Cost of Plating

Professor Baker of the University of Michigan, remarked the dearth of information with regard to the cost of plating. He said that the cost of chromium plating on plug gages, tools and dies seems to be justified because the economy effected makes the use of the product much less expensive. However, Professor Baker called attention to the fact that decorative plating is used, not by the manufacturer but by the consumer, and that it is possible to decrease the cost by the addition of chromium plate to another plate, saying further that the benefits are considerable. He remarked than the samples show the normal difference between the tarnish resistances of the two platings and that there is also some difference in scratch resistance. He agreed with Mr. Phillips that a small amount of chromium upon a substantial base of nickel or of nickel-copper gives a phenomenal increase in salt-spray resistance. He also made a blackboard analysis of the approximate cost of chromium plating.

An exhibit of radiator shells having nickel-plated and chromium-plated tops was an added feature of interest and afforded means of comparing the two kinds of plating.

SECOND PRODUCTION SESSION

X-Ray Examination of Materials Described: Production Training Outlined

A description of extensive researches on the application of X-rays to the examination of automotive materials by Prof. G. L. Clark, of the chemical engineering department of the Massachusetts Institute of Technology, and an outline of the methods of teaching production principles to engineering students by Prof. Myron A. Lee, head of the industrial engineering department of Cornell University, featured the Second Production Session which was held on the afternoon of Jan. 26.

Professor Clark's exposition, in preparing which he was assisted by Robert H. Aborn and Elmer W. Brugmann, was divided into five parts: (*a*) the nature, properties and production of X-rays, (*b*) the application of the differential absorption of X-rays to matter, (*c*) the information obtainable by X-rays concerning the ultimate structures of materials, (*d*) metals and alloys, and (*e*) the constitution and structure of other automotive materials, such as rubber, rubber fillers, asbestos, textile fibers, spark-plug porcelain, lubricants, paints, varnishes, waxes, and the like in relation to their practical behavior. His paper is printed in full on p. 291 of this issue of The Journal.

Training for Industrial Engineering

Professor Lee explained in detail the organization, objects and curriculum of the industrial engineering department and the practical application of classroom work to problems of organization, production control, cost accounting, and time study.

When the department was first suggested in 1904, he said, it was questioned whether sufficient material existed for two lectures per week throughout one term. Now the question is, what to choose from the enormous amount of material at hand. In view of the fact that the men are graduated as mechanical engineers, teaching in this department is confined largely to fundamentals, specific applications being used to impress and drive home the principles. During the third year all students are given an elementary lecture course in industrial organization treating of industrial history, the fundamentals of the division of labor, mass production, standardization, specialization, organization, and the like. In the senior year, the course includes cost accounting, a course in corporation and investment finance, a lecture course in industrial relations, and a course in industrial engineering, consisting of lecture, laboratory and drawing-room work.

The last, continued Professor Lee, consists of a layout for a plant to manufacture some simple piece of apparatus. The first step is to determine the number of machines of each kind that are required. Having done this, floor plans are prepared for a factory to house them. A large variety of problems are then attacked, including such subjects as the development of an organization, mechanisms of control, the use of orders and returns, methods of handling and issuing stores, and of keeping a balance of stores ledger. The work of the functional, time-study and planning departments are similarly considered. After the course in cost accounting has been finished, the student applies the principles to his own plant. Practice in time study is obtained from observing the various machine operations in the university shops.

Features of X-Ray Examinations

An active discussion followed the reading of the papers, during which much additional information was developed. In reply to queries, Professor Clark stated that from successive quantitative studies of parts, such as bearings, and noting the changes that take place, a curve showing the probable life of a part before it has actually become worn out can be plotted; no preparation of specimens is required; the thinner a specimen is, the shorter will be the time of exposure; but the X-rays can be made to penetrate the surface as deeply as desired. X-ray work is not intended to supersede photomicrographic examination, he said, but to supplement it.

Replying to other queries, he stated that the fluoroscope can be used for X-ray examination of materials, and what is needed most now is an X-ray tube of high power, X-ray tubes in Europe using 0.130 amp., whereas the ordinary Coolidge tube in use in this Country uses only from 0.020 to 0.030 amp. Under proper conditions, he said, the refraction diagram of stretched rubber can be seen. The time required to obtain an X-ray photograph of material depends upon the material and varies from a few minutes to several hundred hours. Several companies use the X-ray to make sure that welds are perfect, adhere well to other material and contain no blow holes or imperfections. In examining wires or rolled plates, the view is taken perpendicularly to the direction of working, that is to the axis of the wire. In cold wire-drawing or sheet-metal rolling, certain radial streaks appear in the photograph that indicate perfectly the distortion or bending of the crystal planes. Standards are being set up for cold working.

Application to Heat-Treatment Control

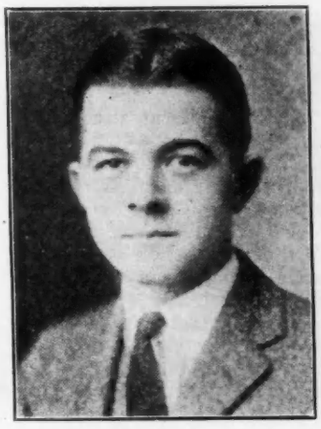
The greatest possibility of practical application of this type of X-ray examination, continued Professor Clark, lies in controlling heat-treatment so that the distortions can be removed or equalized. The study of ceramics is just in its beginning and so far has been confined to differentiating between the various kinds. Although no data have yet been obtained, experiments are now being made of subjecting aluminum alloys to comparative stresses, rapid vibratory bending and other stresses of that kind. Tests such as those of the different degrees of vulcanization of rubber and those of the same compound under different periods of age are also being made. The lines of demarcation in such cases, however, are not as sharp as they are in metals because the structure is that of a very complicated colloidal system. Fiber diagrams of magnetized and non-magnetized steel apparently show no difference. The cost of the General Electric multiple refraction outfit is approximately from $2,500 to $2,800, but the cost of the exposures is not high, being simply a matter of the power expended in the X-ray tube and a certain overhead expense allowed for the apparatus. The greater the number of exposures, the less expensive each becomes.

Any combination of working processes in a material makes itself known immediately by the X-ray, said Professor Clark. When a deforming force is applied to a metal, the crystals will turn differently depending on whether the material is rolled or drawn. If these two operations are combined, complicated stresses result.

With regard to the possibility of discriminating between the various kinds of non-metallic inclusion in steel, Professor Clark stated that Dr. Lester at the Watertown Arsenal had probably done more research along this line than anyone else, but determining the angle of an imperfection requires con-

W. L. Carver

Myron A. Lee



E. W. Brugmann

Robert H. Aborn

A Discusser at the Second Production Session and Three of the Authors

Mr. Carver Discussed the Paper Presented by Professor Lee Outlining the Methods of Teaching Production Principles to Engineering Students and Messrs. Brugman and Aborn Were Co-Authors with G. L. Clark of the Paper on the X-Ray Examination of Materials

siderable experience and the manner of doing so is difficult to describe.

Looking Toward the Future

The principal point brought out in the discussion of Professor Lee's paper was to the effect that the instruction and training of students should be arranged according to their future work. Lieut. W. C. Thee asserted that automotive engineering, with the exception of a few operations, is nothing more than a phase of mechanical engineering. In general, automotive courses, he thought, are too inclusive and cover too many subjects. In his opinion, only the fundamental principles should be studied and the mistake should not be made of drawing illustrations from any particular make of car.

W. L. Carver cited a conversation he had recently with a prominent engineer who commented on the fact that an engineer, although conceiving a project and making the design rarely follows it all the way through. The finish is usually left to a man having financial or general business experience. He asserted that, in a certain plant with which he was familiar, about a half-dozen different systems of accounting were in use.

Mr. Gilmer stressed the importance, during the first few months of a student's course, of giving him an insight into what is to be accomplished possibly 10 or 15 years later. His foundation should be laid with a view to accomplishing certain results.

WHY DOES A FUEL DETONATE?

Measuring and Controlling Detonation by Spectroscopic Methods Suggested

The detonation symposium on the morning of Jan. 26, was notable for the mass of valuable data presented in four carefully prepared papers, Methods of Measuring Detonation, by H. K. Cummings, of the Bureau of Standards; The Detonation Characteristics of Petroleum Motor-Fuels, by S. P. Marley, D. R. Stevens and W. A. Gruse, of the Mellon Institute of Industrial Research; Detonation Characteristics of Automotive Fuels, by Graham Edgar, of the Ethyl Gasoline Corporation; and the Ultraviolet Spectroscopy of Engine-Fuel Flames, by G. L. Clark and A. L. Henne, of the Massachusetts Institute of Technology. Written discussions were also submitted by J. B. Hill, of the Atlantic Refining Co.; W. F. Faragher and W. H. Hubner, of the Research Laboratories of the Universal Oil Products Co., Chicago; Prof. L. C. Lichty, of Sheffield Scientific School; Prof. Daniel Roesch, of the Armour Institute of Technology, and H. A. Huebotter, of Purdue University. Thomas Midgley, Jr., of the Thomas & Hochwalt Laboratories, was chairman of the session.

Mr. Cumming's paper was a survey of the various methods of measuring the anti-detonating qualities of engine fuels now in use. He described in turn the results accomplished by Ricardo; the British Air Ministry Laboratory; Midgley and Boyd; A. L. Clayden; Dr. W. H. Charch, of Ohio State University; Professor Roesch, of Armour Institute of Technology; Leslie, Brown and Hunne, of the University of Michigan; Dr. Roy Cross, of the Kansas City Testing Laboratory; Egloff and Morrell; Olin, Read and Goos, of the University of Iowa; and the Bureau of Standards. Nearly all these methods, said Mr. Cummings, consist of engine tests or rely on engine tests for their interpretation and most of them involve a study of knock intensity. Instruments for estimating knock intensity include (*a*) the ear (sound intensity), (*b*) optical indicators (shape of the pressure-time curve), (*c*) the Midgley bouncing-pin apparatus (the cubic centimeters of gas evolved per minute), (*d*) a galvanometer (electrical conductivity), and (*e*) the diaphragm indicator (the time required to shear a given diaphragm).

Methods of Rating Fuels

In a few instances, continued Mr. Cummings, fuels are rated according to the intensity of the knocking they produce under like operating conditions in a given engine, for example, Clayden's index number. In most cases, however, some engine condition is altered to give the same intensity of knock with different fuels. In the variable-compression engines, the compression-ratio is varied to obtain the highest useful compression-ratio for each fuel, while in other methods of test the compression pressure is altered by supercharging a low-compression engine or throttling a high-compression engine to obtain the maximum mean effective pressure for each fuel. Altering the spark-advance to secure equal intensity of detonation with various fuels in a constant-compression engine is a convenient but less rational method of comparison and the use of this method with multicylinder engines can only be regarded as empirical. Still other methods involve finding, more or less by trial, the quantity of knock suppresser or knock inducer that must be added to a standard reference-fuel to make it equivalent in antiknock value to the fuel under test. Results obtained by such methods may be wholly independent of engine characteristics and operating conditions but this merely shifts the uncertainty from the engine to the reference fuel. The plan offered by Egloff and Morrell for estimating the highest useful compression-ratio of a fuel from the results of chemical analysis is ingenious but too indirect for consideration as a routine method. On the contrary, a simple bomb method that gives, on small samples of fuel, results which can be correlated with the antiknock value of the fuel as determined by engine tests, would be of great value.

Testing by Bombs

More than 1 year ago, Mr. Cummings continued, the Bureau of Standards was asked by the Bureau of Aeronau-

tics to undertake the development of a fairly simple, easily-operated device that could be used to test antiknock value in connection with the purchase of aviation gasoline for Navy use. A bomb was built specially for this purpose. Fuel is measured and injected into the bomb at atmospheric pressure by a precision pump, the stroke of which is controlled by a micrometer screw. Air is then admitted until a predetermined pressure is reached. After a short wait, to ensure vaporization and diffusion, the charge is ignited by a conventional spark-plug. A steel ball in contact with the diaphragm is thrown upward if detonation occurs, the square root of the height of travel being taken as a rough indication of the violence of detonation. Under non-detonating conditions, the ball remains in contact with the diaphragm. The quantity of fuel injected is varied, in actual tests, until the point of maximum detonation is reached for given conditions of pressure and temperature. Results thus far obtained show considerable variation in individual readings, under apparently identical conditions, but the average of groups of readings with various fuels show differences of the same order as are obtained in the Bureau of Standards engine-test.

Mr. Marley, in presenting the paper prepared by Stevens, Gruse and himself, described the researches made on the detonating tendencies of 18 petroleum gasolines by direct engine-tests. His paper is published in full on p. 214 of this issue of THE JOURNAL.

STANDARD REFERENCE FUELS

Dr. Edgar, in presenting his paper, called attention to the fact that, regardless of the method of testing the knocking characteristics of fuels, some reference fuel is essential in each case. The composition of gasoline is so complex and the knocking characteristics of its different constituents are so varied that great difficulty has been encountered in finding one or more hydrocarbons, the purity of which can be definitely established by test and which therefore will be absolutely reproducible. Two hydrocarbons, however, seem to be ideally suited for standard reference fuels, namely, pure normal heptone, C_7H_{16}, and pure octane, C_8H_{18}, which is prepared synthetically from tertiary butyl alcohol. His paper is printed in full on p. 245 of this issue of THE JOURNAL.

The paper prepared by Dr. Clark and A. L. Henne marked a new era in fuel and engine research and, in the opinion of Chairman Midgley, is one of the really great papers presented before the Society. It described the results of a spectroscopic study of the radiations emitted by the gases within the cylinder during explosion, considered in the light of theories of detonation and of the actions of knock suppressers and inducers. This paper is printed in full on p. 264 of this issue of THE JOURNAL.

In a written communication, J. B. Hill confirmed and supplemented the information and conclusions given by Mr. Marley regarding the relation of volatility to detonating tendency. The indicated conclusion, he said, is that the volatility-index affecting detonation is not the end-point, but, as has been suggested, the intermediate danger and, specifically, the 50-per cent point.

NEW METHOD OF RATING FUELS ACCORDING TO EASE OF DETONATION

A detailed description of a new apparatus and method of rating motor fuels in the order of ease of detonation was submitted by Faragher and Hubner in a written communication. By this apparatus, 100 samples of fuel can be tested during the day, and tests made at different times have been found to agree satisfactorily. Reconditioning of the equipment is necessary only after 20 hr. of use. The time required to prepare the apparatus after a period of idleness is 1 hr. Intensity of detonation is measured by a modified bouncing-pin indicator, and motor fuels are matched, by trial and error, with a blend of chemically pure benzene and selected straight-run Pennsylvania gasoline. It is intended to standardize these blends in terms of pure heptane and pure octane, as proposed by Dr. Edgar.

TESTS ON COMBUSTION OF HYDROGEN

A written discussion submitted by Prof. L. C. Lichty, of the Sheffield Scientific School, reported the results of experiments made by Professor Wohlenberg and himself on the combustion of hydrogen in air at high pressures. With the 5 to 1 air-hydrogen mixture, under certain conditions, principally smaller volumes, he said, the combustion process seemed to be the same as that experienced in the detonation of the charge of an internal-combustion engine. Believing that too much credence should not be placed in the maximum pressures obtained with an indicator having a period of vibration so low that the rate of pressure rise will set the indicator into vibration and result in a wavy record, the construction of an indicator is suggested that will give a record that is free from the effect of inertia or period of vibration of the indicator. With such an indicator the behavior of the pressure during and immediately after detonation could be determined. An indicator that will give such a record should have its pressure element located in the wall of the combustion-chamber, should require a large force to obtain a very small deflection, about 0.001 in. or less, and should have its movement greatly magnified by a beam, knife edge, mirror, and point source of light. The indicating mechanism should be a perfectly elastic system, with no friction and with a very high period of vibration.

From what is known of energy liberation and heating of gaseous mixtures, continued Professor Lichty, the abnormally high pressures during detonation in an internal-combustion engine seem to be due to one or more, or all, of the following causes: (*a*) a momentary liberation of energy in excess of what is anticipated, (*b*) an increase of volume larger than the reaction equation of the fuel would indicate, and (*c*) the formation of an unstable compound with a specific heat much lower than that of the products of combustion ordinarily formed. Professor Lichty believes that a correct determination of the maximum pressures during detonation and the behavior of the pressure immediately thereafter might throw some light on the nature of the reaction taking place.

TESTING DETONATION BY SPARK-ADVANCE

Prof. Daniel Roesch, of the Armour Institute of Technology, in a written communication, called attention to the factors that influenced the adoption and development of the spark-advance method of testing detonation at the Institute. The conditions surrounding the spark-advance method of testing, he said, met almost exactly those with which the ultimate user of the fuel must contend, since he uses a fixed-compression engine and varies the spark, and the user's point of view as to what is a good fuel with respect to knocking seems to be accurately duplicated with regard to knock intensity, although not exactly so with regard to intensity of pressure. But the consumer's point of view is with respect to the noises accompanying detonation and not directly with respect to pressure, so that his measure of what is going on in the engine, as indicated by noise, would automatically prevent excessive pressures that cause serious detriment to the life of the engine.

After discussing at some length the advantages and disadvantages of this method of testing, he mentioned, as one of the uses of evaluated antiknock values, the determination of fair relative prices of raw and blended fuels. Certain fuels, he continued, are now available for general distribution, at a premium of from $0.03 to $0.05 per gal. over the market price of the standard product. The distinguishing properties of these fuels include such factors as improved starting qualities, more complete combustion, better antiknock values, and other desirable characteristics that result in more power, less carbon formation or less crankcase-oil dilution.

DETERMINING PRICES OF GASOLINE BLENDS

By curves and tables he deduced a method of determining the comparative price of three such gasolines when mixed with benzol. The three fuels used as examples were a straight-run gasoline of high end-point, a fuel somewhat better than the preceding in antiknock value and a cracked fuel having

the least tendency to knock of the three. In the first example cited, assuming the raw gasoline to have a blend value of $0.18 per gal. and a knock index of 26 and benzol to cost $0.25 per gal., Professor Roesch showed that, for proportions by volume of raw gasoline to benzol of 71 to 29, 79 to 21 and 100 to 0, the values of the blends were $0.151, $0.161 and $0.180 per gal. respectively. When the raw gasoline has a value of $0.19 per gal. and a knock index of 32 and benzol costs $0.25, for proportions by volume of raw gasoline to benzol of 63 to 37, 72 to 28 and 81 to 19, the values of the blends are $0.155, $0.167 and $0.176 per gal. respectively.

Detonation Approaches the Ideal Otto Cycle

H. A. Huebotter, of Purdue University, in a written discussion, made a suggestion. Heretofore, he said, our efforts have been directed to limiting the rate of evolution of the energy of detonation by the use of antiknock compounds. May that not be a makeshift to render the fuel suitable for our present engines? The logical plan of engine development would seem to be to harness the electromagnetic energy of detonation and convert it into mechanical work. The fact that the high-frequency waves of the middle ultraviolet region are produced during the first quarter of the expansion stroke indicates that the constant-volume reaction of the ideal Otto cycle is most nearly approached by detonation.

In opening the general discussion, Chairman Midgley remarked that although the suppression of knocking by the use of colloidal metals had been mentioned by a couple of investigators no one else had ever been able to get the slightest indication of the suppression of knocking by their use.

The Use of Bombs

Regarding the use of bombs, C. H. Brown, of the University of Michigan, stated that he had found the Midgley indicator, when properly adjusted, more free from mechanical vibration than a pin or ball resting on a diaphragm.

The Celebrities at the Detonation Session

1—H. K. Cummings, 2—Dr. Graham Edgar, 3—George L. Clark, 4—Chairman Thomas Midgeley, Jr., 5—Dr. W. F. Faragher and W. H. Hubner, 6—Dr. S. P. Marley, D. R. Stevens and W. A. Gruse, 7—L. C. Lichty, 8—Lieut. W. C. Thee, 9—Dr. R. E. Wilson and 10—Dr. J. B. Hill

Explosions, he added, are of two types: (*a*) the ordinary detonation-wave discovered by Dixon in England and (*b*) the type that apparently takes place in the engine. Bombs occasionally give results that are absolutely wrong, but he thought it might be possible, by changing the dimensions of the bomb and watching other factors to ensure the obtaining of a type of explosion similar to that developed in an engine. He believed that results obtained with bombs were satisfactory only when the tendency to knock is directly proportional to the rate of rise of pressure of the fuel.

R. E. Wilson, of the Standard Oil Co. of Indiana, stated he had come to the conclusion that it is absolutely necessary to make antiknock tests in the engine. He stressed the importance of comparing fuels at the same mixture-ratio. A certain fuel at a given mixture-ratio will develop the same torque without knocking as will a better fuel at a leaner mixture-ratio. Considerable misunderstanding, he thought, arose from comparing fuels with benzol blends, inasmuch as some carbureters give marked enrichment with benzol blends; consequently, the benzol blends show up more favorably than others. For routine testing, all that is necessary, he said, is to set the carbureter and open the throttle until audible knocking begins.

To H. A. Huebotter's query whether it is common practice in such tests to keep the spark-advance constant, inasmuch as this had not been customary in tests he had made, Mr. Lowry, of the Bureau of Standards, replied that this depended on the type of test; that as only the maximum mixture-ratio was of interest in this case, the spark-advance of the maximum was fairly definite and varied little at constant speed within a moderate range; with variations of speed, however, comparisons might be affected. That was in accordance with his finding, asserted Mr. Huebotter, but in economy tests and in those with lean mixtures, small changes in the timing affect the torque appreciably.

Importance of Engine Tests of Fuel

Mr. Wilson was glad that both Mr. Marley and Mr. Faragher did not recommend analytical methods as a substitute for engine tests. To do so, he thought, would be misleading. Percentages, he said, must not be taken too seriously, for analyses of hydrocarbons are not the same as those of inorganic material. They are based on different solubilities. Three published methods with which he is familiar give results that vary from 3 to 25 per cent.

Mr. Brown, replying to a query as to the reason for the knocking tendency of heptane and the non-knocking tendency of octane, mentioned by Mr. Edgar, stated, as a hypothesis, which explained many discrepancies, that two properties of a fuel determined its tendency to knock, namely, the rate of rise of pressure and the ignition temperature.

When asked to discuss Dr. Clark's paper, Lieut. W. C. Thee explained that detonation, to his mind, was nothing more than a rapid rate of flame propagation; that the gasoline burns around the spark-plug first, and, as it begins to burn, ultraviolet rays go ahead of the flame-front, penetrating the unburnt fuel, activating the molecules and putting them in condition to "pop off." The rays have not a heating but a sort of radiation effect, so that, when the molecules are finally ignited, they "go off with a bang."

If the rate of flame propagation is normal, added Lieutenant Thee, no knocking will result and a short spectrum band will be formed in the photographic plate. If the rate of flame propagation is greater than normal, a long and continuous spectrum, extending into the ultraviolet region, will be obtained. If it is below normal, a spectrum in the infrared region will be formed on the photographic plate, which shows that the rate of flame propagation is slow. This causes the engine to overheat.

Sticking to Fundamental Mechanical Conceptions

Dr. H. C. Dickinson suggested that it might be worthwhile to avoid getting too far away from some of the comparatively fundamental mechanical conceptions that should be borne in mind in any attempt to make a detailed analysis of the detonation problem. He sketched an endless tube on the blackboard and recalled some of the theories expressed by Mr. Midgley several years ago. Does the measurement of radiation, he asked, tend to explain what happens, or is what happens mechanically the cause of the phenomena of radiation? He thought the fundamental mechanical cause might, after all, be a simple thing, possibly tied up with the molecular or atomic structure of the fuel.

In Mr. Wilson's opinion, during detonation, some sort of activation of the flame-front is absorbed by the materials. Different fuels vary in the type of radiation, he said. Antiknock agents differ in the extent to which they absorb the radiations. He believed this theory accounts for most of the known facts.

Mr. Brown remarked that although, in a bomb, increasing the temperature prevents the setting up of the detonation wave, increasing the temperature in an engine makes the knocking worse. In an engine something seems to happen ahead of the flame, due to radiation.

In closing the discussion, Chairman Midgley recalled some recent experiments made with bombs made of Pyrex glass, of which instantaneous photographs had been made. He predicted that the detonation problem would be solved as soon as some one had nerve enough to build a cylinder-head of quartz glass.

COOPERATIVE FUEL-RESEARCH SUMMARY

Conclusions Drawn From 5 Years' Investigation: College Research a Topic

Whatever might be a person's interpretation of what was best in research, an assemblage of conclusions based on a series of scientific investigations, laboratory or test findings readily translatable into terms of practical usage, knowledge of the accomplishments in this field of our institutions of learning, or summaries of fundamentals to serve as a guide as to the state of an art, he would have found material to meet his requirements presented at the Research Session of the Annual Meeting. Dr. H. C. Dickinson, chairman of the Society's Research Committee, presided and presented a paper entitled The Cooperative Fuel-Research to Date; Dr. C. S. Cragoe presented a paper prepared by himself and J. O. Eisinger on Fuel Requirements for Automotive Engine Starting; the subject of the joint paper of Prof. A. A. Potter and Prof. G. A. Young was Tendencies in Research at Engineering Universities; while the program was brought to a conclusion by the reading of a Progress Report of the Research Subcommittee on the Causes and Effects of Detonation, by Thomas Midgley, Jr., chairman of the Subcommittee.

In Dr. Dickinson's summary, which is published in this issue of The Journal on p. 193, the audience was given a bird's-eye view of the Cooperative Fuel-Research since its inception 5 years ago up to the present. Other papers printed in the past have reported in detail the various projects included in the joint investigation of the American Petroleum Institute, the National Automobile Chamber of Commerce and this Society, which was carried out at the Bureau of Standards, Dr. Dickinson's presentation drew in broad, general strokes the picture of the entire research, showing how each of the parts contributed to a well-assembled harmonious program and indicating some of the conclusions that might be drawn from the results obtained in the test work.

The development of the cooperative fuel investigation, as traced by Dr. Dickinson, is a splendid example of the natural growth of a research project. The first question proposed for solution was, what grade of gasoline would afford the maximum number of car-miles of transportation per barrel of crude oil used in its production. Economy, according to the conclusions drawn from this first section of the research, dictates the use of as heavy a fuel as possible, but a practical limit in this direction is set by the dilution of crankcase oil and the difficulty of starting. These two last topics were then made the subject of investigation. The next step was to fill in the gap in the course of engine performance left by the two projects, one concerned with normal running and the

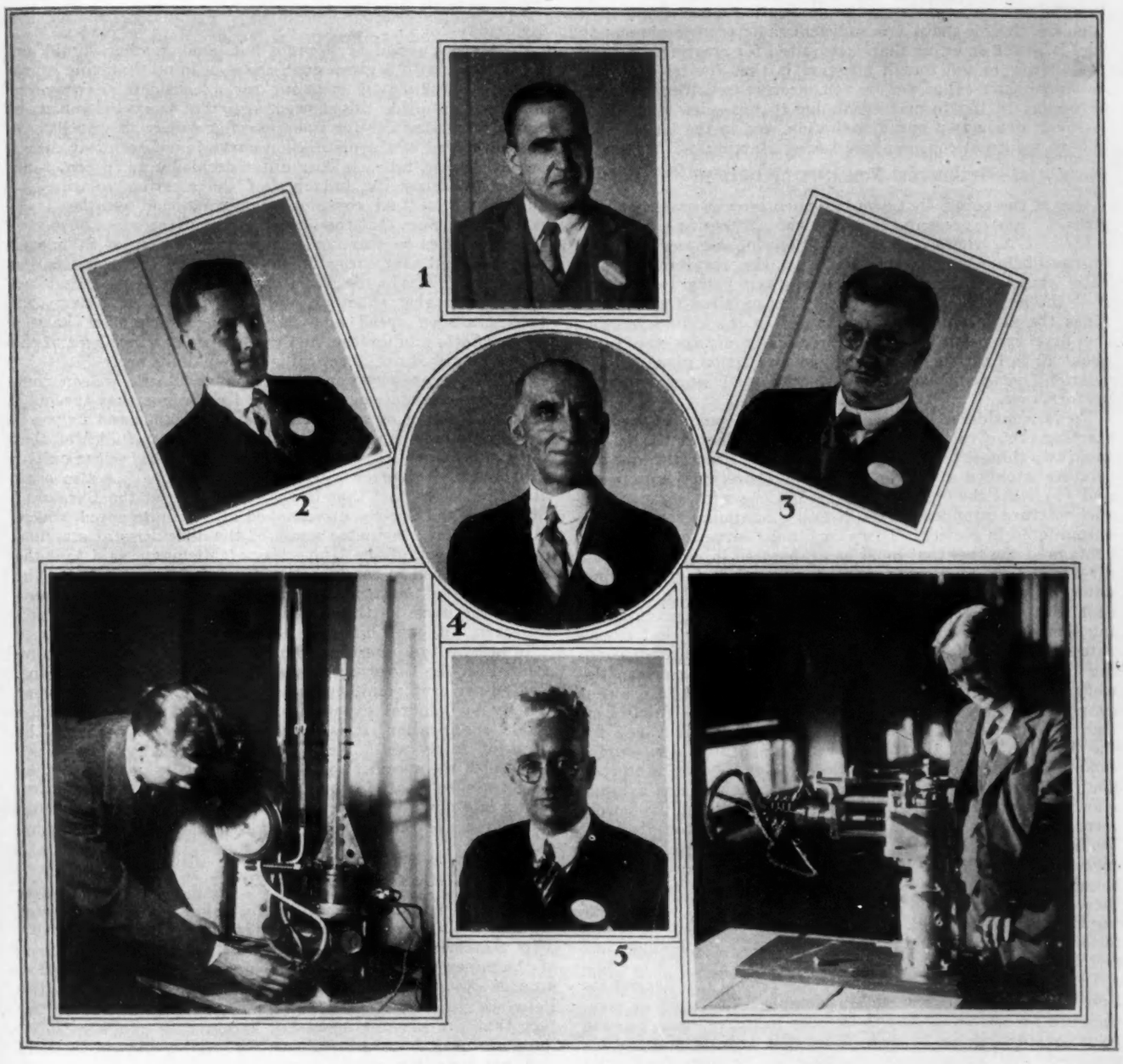
other with starting, and to study the behavior of an engine during the warming-up and acceleration period. This work is now being carried on.

Among the tangible results that have come from the work are the development of test methods, and the furtherance given toward the goal of maintaining the best practicable adjustment of the engine to the fuel and the fuel to the engine with a view to maximum over-all efficiency. Of equal, perhaps greater, importance have been the intangible results, the impetus given to fuel research in both the petroleum and automotive industries and the drawing together of both in a cooperative and heartily friendly effort to solve their common problems.

Vital Fuel-Questions Answered

In his paper, Dr. Cragoe performed for one phase of the fuel research somewhat the same service rendered by Dr. Dickinson for the entire investigation. Taking for his subject Fuel Requirements for Automotive-Engine Starting, he correlated the results of more than 1 year's careful study on this topic. With his more limited field, he was also able to carry his analysis farther and to reduce the findings to such form that they could be practically applied in specifying fuel to meet starting requirements in any locality, winter or summer.

At the outset of his paper, Dr. Cragoe set for himself the problem of answering four definite questions. The first two are of importance to the consumer and the producer of fuel: what are the fuel requirements for satisfactory starting of cars now in service throughout the Country; and what constitutes a suitable means of ascertaining whether or not the fuel meets such requirements? Of vital importance to the Nation as a whole from the standpoint of fuel economy and conservation of natural resources are the second two ques-



The Chairman and Authors at the Research Session

Dr. H. C. Dickinson, Chairman of the Session (4); J. O. Eisinger (1) and Dr. C. S. Cragoe (2) Discussed Starting and Acceleration Tests, G. A. Young (3) Discussed Tendencies in Research at Engineering Colleges and W. E. Lay (5) Was Active in the General Discussion. The Bomb Developed by the Bureau of Standards for Measuring Detonation Is Shown at the Lower Left and the Jacklin Indicator at the Lower Right

tions: is the fuel better or worse than required; and if so, how many gallons of fuel produced annually in the Country can properly be charged to waste on this account.

After an extremely competent analysis of the various factors entering into the problem and the methods taken to solve it, Dr. Cragoe concluded by giving the answers indicated by the information contained in the paper. The first question is met by the statement that the fuel requirements for engine starting depend largely on the temperatures anticipated in service. These temperatures are fairly well known for any given locality from Weather Bureau statistics. Replying to the second, Dr. Cragoe pointed out that two points on the standard American Society for Testing Materials distillation curve appear to be an adequate means of specifying the fuel to meet given requirements. Conversely, these points on the distillation curve seem to determine the temperatures at which a given fuel is most suitable for engine starting. A knowledge of the fuel requirements for each season in any locality and two points on the distillation curve for a given fuel, Dr. Cragoe showed, is sufficient to determine whether the fuel is better or worse than is required for starting. Finally, the answer to the fourth question is that fuel either better or worse than called for by temperature requirements leads to waste; in the former event due to excessive evaporation losses in production and distribution, and in the latter traceable to too great consumption during starting.

Guide for Fuel-Specifications

One of the points that aroused much interest was the development and presentation of the following equation: $r_a/r_e = 2/N$, where r_a is the resultant fuel-air ratio attained in equilibrium air-distillation, r_e is the resultant fuel-air ratio attained in engine cylinders when firing begins, and N is the number of engine revolutions required for starting. Since the resultant mixture attained in the cylinders when the first explosion occurs is practically always the same, about 20 to 1 air-fuel ratio, the above equation gives a direct relation between fuel-volatility data and engine-starting performance.

To be considered satisfactory from the point of view of starting, Dr. Cragoe then pointed out, a fuel must be able to do two things: (*a*) provide possible starting with a 1 to 1 mixture supplied at the lowest temperature ever anticipated and (*b*) start the engine in 10 revolutions with a 2 to 1 air-fuel mixture supplied at the average minimum temperature encountered in service. These conditions serve to fix the percentage of the fuel that must be evaporated in an equilibrium air-distillation to give possible and satisfactory starting, namely 5 per cent with a 1 to 1 mixture supplied, and 15 per cent with a 2 to 1 air-fuel mixture. Tables are given showing temperatures corresponding to 5 and 15 per cent evaporated in the equilibrium air-distillations with the corresponding distillation temperatures specified by the American Society for Testing Materials. In each class, 5 and 15 per cent evaporated, the ratio of absolute temperatures is fairly constant. Using the mean values for the ratios, namely 1.38 for the 5 and 1.35 for the 15 per cent evaporated, Dr. Cragoe compiled a table of American Society for Testing Materials distillation temperatures corresponding to lowest and average starting temperatures. In other tables he listed the lowest recorded and the mean minimum temperatures for about 30 localities as determined from Weather Bureau statistics covering a period of from 20 to 50 years, separate figures being given for each month. The information supplied in these tables furnishes a direct and ready means for specifying the fuel to meet the starting requirements used as a criterion, for a large number of localities and for both winter and summer.

To illustrate the application of the tables, Dr. Cragoe selected the city of Detroit as an example. The summer fuel, designed for use from May to October inclusive, must provide possible starting at 24 deg. fahr., the lowest temperature recorded, and satisfactory starting at 55 deg. fahr., the average minimum temperature. The American Society for Testing Materials distillation temperatures should therefore be 208 deg. fahr. at 5 per cent, and 250 deg. fahr. at 15 per cent evaporated. The winter fuel, for use from November to April, inclusive, must operate at as low a temperature as —24 deg. fahr. and at the average minimum temperature of 26 deg. fahr., to do which it must have American Society for Testing Materials distillation temperatures of 141 and 193 deg. fahr. at the 5 and 15-per cent points respectively.

Other Points of Analysis

Some of the points brought out by Dr. Cragoe in his analysis of criteria of the starting characteristics of fuels are that the first 20 per cent distilled in the American Society for Testing Materials distillation test is the portion most closely associated with engine starting; that, due to thermometer lag and distillation losses this method of testing cannot give an accurate picture of the curve below the 5-per cent point; that a qualitative relation does exist between the distillation curve and the starting ability of a fuel but that the air distillation data were necessary, as a connecting link, to interpret the result of engine-starting tests directly in terms of the American Society for Testing Materials distillation curves.

In his discussion he brought out, among other significant facts, that, with a given fuel, the consumption during starting is approximately constant for a considerable range of mixtures supplied. He showed, also, that while the consumption during starting for fuels varying widely in volatility at the lower end of the distillation curve is not seriously different at 68 deg. fahr., it does differ decidedly at 36 deg. fahr. This emphasizes the influence of the starting volatility of fuels on total fuel consumption during cold weather. He pointed out, also, that the limited study of the effect of engine characteristics on starting made at the Bureau of Standards had indicated that throttling and choking; the size, location and obstructions in the jet; and the heating of the liquid fuel had considerable effect on starting; jacket-water temperature, cranking speed and the combustion-chamber have a minor effect; and ignition and the internal surface area of the intake-manifold are practically without influence.

After the presentation of the paper, R. E. Wilson commented on the statement made by Dr. Cragoe that the influence on starting of such factors as lubricants and valves is probably minor or practically nil. Mr. Wilson indicated that some laboratory experiments with which he was familiar gave results at variance with this statement. He also drew attention to the fact that in the tests made at the Bureau of Standards the engines are cranked at a definite speed, which, in his opinion, eliminated many of the difficulties of starting.

C. H. Brown, of the University of Michigan, said that the results obtained in the investigation being carried on for the Association of Natural Gasoline Manufacturers were practically the same as those obtained in the Cooperative Fuel-Research, although different methods had been employed.

In answer to a question from the floor, Dr. Dickinson commented on the Government specifications for motor-gasoline. The 90-per cent point, he said, is a compromise, based very largely on general experience. It is not ideal, but, for a single specification, it is probably the one that meets the situation fairly well. As far as starting characteristics are concerned, the specifications mean practically nothing. They do not assure a satisfactory starting-gasoline and the requirements laid down by them as to the lower end of the distillation curve are far exceeded by gasolines marketed commercially.

Automotive Research in Colleges

The total annual expenditure by engineering colleges for organized engineering research is more than $1,000,000. This statement made by Prof. G. A. Young in the course of the paper prepared jointly by him and Dean A. A. Potter aroused great interest on the part of the audience at the Research Session. It acquires greater significance from the fact that the amount spent for research is roughly 1/13 of the sum spent by these colleges for undergraduate instruction, not including certain factors of interest or depreciation of educational plants.

The expenditure of this money is allocated among about 40 colleges that are carrying on organized engineering research. In nine institutions the funds for this purpose came

purely or entirely from State appropriations and these State grants amounted to about $123,000 in the college year 1924 and 1925. In the same scholastic year about 20 institutions set aside a total of about $451,000 in their engineering college budgets for engineering research. In the college year 1924 and 1925, 15 engineering colleges received more than $500,000 for research through cooperative relations with industry.

After emphasizing in a general way the amount of research being carried on in engineering colleges, Professor Young presented an impressive and detailed list of the scientific investigations carried out at a number of these institutions in the college year 1925 and 1926. In this compilation he mentioned in practically every instance the type of project that was being carried out, the amount of money that was planned to be expended and the source from which it was derived.

A plan selected by Professor Young as of particular interest is the one that has been in force in the Massachusetts Institute of Technology since 1919. This is a cooperative arrangement whereby industrial organizations in search of aid in scientific and engineering research pay the Institute stated sums of money as retainer fees for a period of 5 years in return for which they have at their disposal, within certain limitations, the research staff and facilities of the Massachusetts Institute. The agreed-to services to be rendered by the Institute include the use of the libraries, consultation with members of the staff, advice as to where special problems may be solved or tests carried out, and the making available of alumni records to aid the contracting industrial organizations in locating desirable men. Prof. Charles L. Norton, director of the Division of Industrial Cooperation and Research, is quoted as estimating roughly that the amount of money spent at the Institute for industrial research under this plan has been in excess of $175,000 annually.

The amount of money appropriated by automobile building companies for research work in colleges and universities was brought out by Professor Young in the next section of his paper, in which he made a resume of the cooperative research by State and National engineering societies, associations and private manufacturing companies during 1925 and 1926. Manufacturing companies, in general, use 67 colleges for research and are interested in 34 projects. Automobile companies are interested in four investigations being carried out at four universities. The annual appropriations of all manufacturing companies amount to more than $100,000; while those of automobile builders totaled only $5,900.

Professor Young also mentioned the investigations directly and indirectly of interest to the automobile industries that have been made by colleges on a non-cooperative basis. Equipment tested has included engines, carbureters, manifolds, spark-plugs, pistons, piston-rings, radiators, starting and ignition systems, dust collectors, oil-purifiers, tires, lubricating oil, and fuels. The effects of detonation, high compression, air resistance, riding-qualities, acceleration possibilities, brakes, and other features have been covered. Purdue University, of which Professor Young is a representative, has expended in the last 8 years more than $150,000 for research of direct interest to the automotive industries. Included in the investigations made are the well-known studies of problems of carburetion and the flow of heat in pistons. In connection with the latter project, a well-equipped piston-testing plant has been set up and maintained.

2,000,000 Technical Men Needed

The demands in this Country for the next 10 years for technically trained men will call for an output of the universities of about 2,000,000, was the estimate made by F. F. Chandler in commenting on Professor Young's paper. Some of these men will have to be trained for research, he said, and certain universities are performing a valuable service in giving students a fundamental grounding and assisting graduates to find the sphere for which they are fitted. If the colleges are to fill this function capably, they must maintain contact with industry and Mr. Chandler urged that automotive engineers help bring to institutions of learning the viewpoint of industry.

Prof. G. B. Upton, of Cornell University, in a written discussion read by Thomas Midgley, Jr., expressed the opinion that the main research function of universities is not to develop new and fundamental data in the realm of pure science, but rather to find and train young men adaptable to the conduct of research work. These men, after a start at the university, will be fitted to accept positions on the staffs of industrial and research laboratories throughout the Country.

J. H. Hunt assigned two reasons for the small amounts contributed by the automotive industry to engineering research in universities. The first was that the automotive industry is competitive, while the appropriations for colleges come largely from organizations that are more monopolistic in nature, such as railroads and public utilities. The second was that automobile companies want a speed in arriving at results that universities, with their limited staffs, are unable to attain.

Some further information as to the way in which research is carried out at universities was given by Prof. W. E. Lay, of the University of Michigan, who showed slides illustrating the universal test-engine recently acquired by the institution, and by Prof. H. A. Huebotter, of Purdue University. The latter differentiated the research carried out at Purdue into three classes, fundamental, developmental and the training of students in actual laboratory work.

In closing the discussion, Dr. Dickinson deprecated the fact that this Country does not occupy an outstanding position in the development of fundamental ideas on which progress is based. In his opinion, the contribution to the major generalizations upon which all engineering development depends is preeminently the field of universities. The function of the university is to foresee the fields in which the industries of the Country need further advances in basic knowledge.

Detonation Subcommittee Reports

The last item on the program was a brief progress report of the Research Subcommittee on Causes and Effects of Detonation that will be printed in full in the Automotive Research section in an early issue of THE JOURNAL. This Subcommittee, which was appointed at the June, 1926, meeting of the Research Committee, consists of Thomas Midgley, Jr., chairman, who read the report; T. G. Delbridge, who was represented at the Annual Meeting by J. Bennett Hill; S. W. Sparrow; and R. E. Wilson. C. M. Manly suggested the formation of the Subcommittee, which had its origin in the thought that the Society's Research Committee, as such, might contribute to study of detonation, aside from the investigations on this subject as part of the Cooperative Fuel-Research. The Subcommittee's function is not to initiate research but to keep abreast of what studies are being made of detonation, with a view to formulating summaries of those findings that are firmly established and commonly accepted by the automotive engineer.

Prof. H. M. Jacklin, of Ohio State University, contributed to the discussion by describing a variable compression-head that gives a compression range of from 3¾ to 6½ to 1. With the aid of slides he made a report of some tests on detonation carried out with the aid of this apparatus. Professor Jacklin also exhibited and demonstrated the engine indicator developed by him. Much attention on the part of those in attendance at the Research Session was given to this device, which was also shown at the Semi-Annual Meeting last year. Those who had the opportunity of seeing it at that time sought more information concerning it, and a number of engineers who had never seen it before expressed great interest in its operation.

ACTIONS TAKEN BY SECTIONS COMMITTEE

Endorses Inter-Section Membership Competition; Continues Student Committee

Through the action of the Sections Committee, taken at its dinner meeting on the evening of Jan. 26, a new element will be injected into Sections' membership work, the spirit of healthy, friendly inter-Section competition based on a plan that will give a fair rating to all the different territories. The meeting was a joint gathering of the members of the 1926 and 1927 Sections Committees, and was attended by representatives of the majority of the Sections, as well as by members of the Council and the Constitution Committee. J. H. Hunt, chairman of the 1926 Sections Committee opened the meeting by thanking the members of that body, and in particular the Subcommittee on Student Activities for their active and effective cooperation in the last year. He then handed over the gavel to F. F. Chandler, chairman of the 1927 Committee, who presided for the remainder of the meeting.

The suggestion for formulating some plan whereby all Sections could be placed on an equal footing in a membership campaign competition came from F. K. Glynn, chairman of the Membership Committee. His proposal was that the Sections be rated in membership by the proportion of Section members to Society members in their territory. This would overcome the advantage possessed by the favorably located Sections which can, with less effort than need be put forth in other territories, acquire a numerically large membership. In a letter transmitting his suggestion and asking for the cooperation of the Sections Committee in the membership work, Mr. Glynn also urged the effective registration of guests at all Section meetings and the prompt following-up of these guests to gain new members.

After some discussion of Mr. Glynn's suggestion, the meeting passed a motion endorsing the principles embodied in it and calling for the appointment of a committee of three members, the Chairman of the Sections Committee, the Chairman of the Membership Committee and C. F. Clarkson, to investigate the feasibility of the plan and decide on the details of its execution.

R. E. Plimpton, chairman of the Subcommittee on Student Activities, submitted a report of the work of this group since its organization last July. As charged, the Subcommittee examined the proposed charter submitted by the Student Group at the Ohio State University and recommended certain changes in it which were thought to be advisable. To secure larger Society enrollment among students, the report recommended that a continuing campaign be developed intended to familiarize engineering schools with various phases of the automotive industry. The suggestion was also advanced that Sections hold meetings of especial interest to the students, invitations to such gatherings being extended to members of the faculty as well as the student body. Other topics treated in the report were increasing interest in automotive topics among engineering students and the formation of additional student groups.

Acting on the request of the Council, Chairman Chandler asked for an expression of the Sections Committee as to the place of holding the Semi-Annual Meeting this year. A number of available locations, the possibilities of which had been previously investigated, were presented for consideration. These places were discussed from the many angles that have a bearing on their suitability as Semi-Annual Meeting headquarters, geographical situation, railroad facilities, climate, living, and sports accommodations. Votes were taken representing, first, the personal opinion of those present, and second, their interpretation of the wishes of their Sections. In both polls, French Lick Springs won first place.

A final subject discussed was the question of revising the provisions in the Society's Constitution for the election of Vice-Presidents. The question was discussed at the last meeting of the Council and the suggestion made that the situation be outlined at the Sections Committee meeting so that the Council might have the benefit of the opinion of the Sections Committee members. A. J. Scaife, chairman of the Constitution Committee, reported on the consideration given by that body to the situation. Discussion was had as to whether a revision should be made, and if so, which of a number of suggested plans was the most advisable to follow. The action taken was to recommend to the Council that a chart showing the proposed schemes of constitutional revision be prepared and sent to the governing boards of the various Sections for their consideration and report.

EVOLUTION OF THE SMALL LIGHT-CAR

English and American Light-Car Practice Contrasted as Aid to Future Design

The great difference between the conditions in England and other European countries and those in the United States was emphasized at the Light-Car Session that was held on the morning of Jan. 27. The difference is composed of such factors as road conditions, taxes, the characteristics of the respective peoples, and what sort of car they need to satisfy their particular demands best. The paper on The English Light-Car and Why was by Alan R. Fenn, of the Sunbeam-Talbot-Darracq Combine, and is printed in full elsewere in this issue of THE JOURNAL. The American viewpoint was presented in the paper delivered by Fabio Sergardi, engineer for the Reo Motor Car Co., Lansing, Mich. Nearly 250 members and guests attended this session and evidenced their interest by the numerous questions they propounded for discussion after the papers had been presented. President T. J. Litle, Jr., was chairman.

Following the presentation of Mr. Fenn's paper, Chairman Litle remarked that the statements made by Mr. Fenn to the effect that the sale of American light-cars already introduced into England has fallen off is not surprising because the cars in question have not met the English conditions and public demands successfully. He said that, as public demand changes in this Country, the builder will change his design and his ideas of construction. He predicted that the English light-car and the American light-car will be more nearly identical about 1 year from now, basing this statement on Mr. Fenn's prediction that the coming English design will be slightly heavier and have six engine-cylinders instead of four with the engine-power somewhat increased thereby. He remarked that the same tendency exists now in the United States.

H. M. Crane agreed with Mr. Fenn that rating the lightness of a car by the size of the engine is not strictly accurate, although it is the usual method in England, but it is a method that is not a natural one in this Country for reasons which center largely in the advertising departments of the car builders. Mr. Crane's opinion is that operating cost of a car probably depends primarily on its weight. Then comes the question of whether a car can be made light in some one way that is better than another, which calls for an engineering compromise. The preponderating influence on the weight of a car is due to its linear dimensions, the tread and the wheelbase, and these are determined by certain local conditions.

Commenting on the subject of the width of tread, which is approximately 56 in. in this Country, Mr. Crane stated that the width of tread makes no difference on many thousands of miles of roadway in America, although he said that enough main highways still exist on which ruts present difficulties for this fact to have a very serious bearing on the quantity production of a car as regards the tread. He said that it probably would be much easier to sell a $7,000 car with a narrow tread in this Country than to meet the requirements of the public with a car to sell at $500. He remarked also that the tread is not only related to the subject of ruts in the roadway but also is influenced by the seating capacity desired. Not only is the width of tread related to the passenger-carrying capacity of the car, but the length of wheelbase also is determined by carrying

FABIO SERGARDI, ALAN FENN AND L. MELANOWSKI

Alan Fenn, of the Sunbeam-Talbot-Darracq Combine, Presented a Paper on The English Light Car and Why and Fabio Sergardi Presented a Paper on How Small Should a Light Car Be? at the Light-Car Session. L. Melanowski Took an Active Part in the Discussion

capacity because the controlling dimension on a car having four doors is the longitudinal distance from the rear of the steering-wheel to the front of the rear wheel, provided that the steering-column is located in comfortable relation to the pedals.

In reply to a question as to whether there would be any difference in the design of the English light-car if the tax were based on other considerations in place of being based on cylinder-bore, that is, whether the development of the English small-bore, high-speed engine, low gear-ratio car is the result of actual engineering advantage to the user or is more in obedience to the arbitrary tax imposed, Mr. Fenn said that the engineering fraternity was not consulted, the tax is purely a political proposition and, if the tax were taken off, this would cause a radical change in the situation with regard to car design.

B. B. Bachman concurred with Mr. Crane that to translate the foreign light-car to this Country before carefully considering the logical engineering development that should be based on such conditions as traffic, the topography of the country, the character of the roads, and the layout of the towns, all of which are so different and so widely variable, is totally unjustified.

With reference to the subject of parking, Mr. Bachman said that it undoubtedly is true that those who are familiar with the restrictions on the operation of the motor-vehicle as the American wants to use it, due to the increasing congestion in the larger cities, believe that a revision of design which will restrict the dimensions and which will enhance the ability to maneuver a car would be a step that would increase still further the usefulness and the adaptability of the automobile to the purposes of personal transportation, but Mr. Bachman feels that a grave question exists as to whether revision of design is the only solution possible. He acknowledged that this is one means of overcoming the difficulty but said that it seems to him that we must take a broader outlook and consider what can be, should be, or probably will be done as a matter of evolution. He predicted that one result of the development of the small light-car will be not merely a tendency to make the automobile a compact machine but probably will result also in dispersion of industrial and sales activities, particularly in regard to retail sales.

In reply to J. H. Hunt's question regarding engine weight, Mr. Fenn said that practically all the cars which he mentioned are built with the transmission attached to the engine and therefore he could state only the range of weight for the two combined, this being from 296 to about 350 lb. Further questions by the various discussers were directed mainly toward bringing out additional explanation of the details of Mr. Fenn's paper.

HOW SMALL SHOULD A SMALL CAR BE?

Mentioning that one of the first developments of the automobile was a small car and the car has grown in size ever since, Mr. Sergardi went on to enumerate various makes of car that were pioneers in the small-car class and to comment thereon regarding their design and capacity. He then spoke of the small car that has been developed in England to meet the demand for cheaper means of transportation, saying that of a total of 133 models, 76 have a piston displacement of less than 120 cu. in., and this has caused some of the automotive executives in the United States to wonder if some such car will not be the great conveyance of the future. But he believes, after studying the situation, that the class of small car needed abroad and the class of a similar car needed in this Country are decidedly different. For that reason he analyzed the two different markets separately.

Mr. Sergardi called attention to the fact that the actual size of the small car that seems to be needed in this Country is not yet clearly defined in the minds of automotive engineers. Various opinions are held regarding price, weight, wheelbase, speed, and the like. He, therefore, analyzed the existing low-price cars on the United States market in an endeavor to reach some definite conclusion concerning the so-called ideal small car and its possibilities and compiled the table that is printed on p. 192.

Considering what the chief advantage might be for the public to buy a car smaller than the ones already on the market, he said that price seems to be the only powerful reason which can induce the buying public to look upon this

DATA CONCERNING AMERICAN SMALL CARS [1]

Details	Name of Car					
	Ford	Chevrolet	Essex	Pontiac	Olds	Small Car
Bore, in.	3¾	3 1/8	2 1/8	3¼	2¾	2¾
Stroke, in.	4	4	4¼	3¾	4¾	4⅛
Number of Cylinders	4	4	6	6	6	4
Ratio of Stroke to Bore	1.07	1.10	1.58	1.16	1.73	1.50
Displacement, cu. in.	176.7	170.9	144.6	186.6	169.3	100.0
Wheelbase, in.	100	103	110½	110	110½	96
Torque, lb-ft.	1,140	1,110	940	1,210	1,100	650
Diameter of Wheels, in.	30	30	30	29	30	28
Gear-Ratio	3.63	3.82	5.60	4.18	4.73	4.70
Weight of Car, lb.	1,960	2,130	2,400	2,350	2,460	1,200
Weight of Passengers, lb.	750	750	750	750	750	700
Total Weight, lb.	2,710	2,880	3,150	3,100	3,210	1,900
Power-Weight Ratio	0.102	0.098	0.111	0.112	0.108	0.114
Price of Car	$495	$645	$695	$825	$950	$380
Type of Car	Tudor	Coach	Coach	Coach	Coach	....
Price of Car, cents per lb.	25.25	30.25	28.80	35.25	38.50	32.00

[1] Figures taken from 1926 statistics published by *Automotive Industries*.

car favorably. Although the operating cost is a point to be considered, he believes it to be a secondary consideration in this Country and, therefore, is of the opinion that price alone is a paramount factor. Regarding how low this price should be, based on statistical data applying to the lowest-price cars at present on the American market and considering weight, wheelbase, engine displacement, and horsepower, Mr. Sergardi notes that the difference in price from one class to another varied from $50 to $150 which means that, to attract the attention of the buyer, the price of the small car in question should be from $50 to $150 less than that of the existing low-price cars. He considered in brief detail the prices of several well-known makes of small car now on the market and said that the ideal car under consideration, finished at least as well as they are and built to carry five passengers, should be sold for say an average of $380 and that it would weigh approximately 1200 lb.; but he doubts that this can be done because the difference in price between the small cars now built and the ideal car would be about $115, and he thinks that the advantage will still remain with the cars now built.

The European Type of Small Car

Calling attention to the very great differences between the automobile situation in Europe and that in this Country, the speaker remarked that an automobile of any sort is considered a luxury abroad and that the members of the middle class in general, which would constitute the largest class of buyers, are financially unable to own a car at any price. He remarked also the high price of gasoline abroad, the high taxes on motor-vehicles, the high maintenance cost, and the lack of garage space in the larger cities as factors that prevent the buying of cars. He mentioned several makes of foreign-built small-car, saying that their builders have reduced the price to the lowest possible European level but that still they are far from reaching the masses and that this is parallel to the situation in the United States.

American-Built Car for Export

Commenting on the possibility of an American-built small-car to meet the European demand, he said that such a car must be somewhat smaller than the smallest American five-passenger car. Its requisites should be lighter weight, a shorter wheelbase and perhaps a narrower tread. The engine should have about 100-cu. in. capacity and a gasoline consumption of at least 30 miles per gal. If such a car were finished somewhat better than the present American low-price cars, he believes that the car could not fail to be a good competitor in the European market.

Considering this supposed export-car for use in America, Mr. Sergardi repeated that it would be lighter than any present American car, would have less power, possibly a shorter wheelbase, and the price of the car would be higher than that of the American car in this class. He questioned the advantage to anyone of buying such a car, calling attention again to the conditions which influence the European buyers and which he said are not factors of equal weight with the prospective American buying public. The possibility of low operating-cost would, he believes, be considered such a secondary benefit by an American that its influence would be negligible.

In conclusion, Mr. Sergardi stated his belief that, in Europe, so long as the tax on automobile horsepower and the price of gasoline remain high, the small car always will be predominant and that it will be low powered, light in weight and diminutive, in comparison with the present American low-price car. The speaker noted a tendency in America today to refine the low-price car, giving to it more style and a better finish. He noted also indications that some radical change regarding the number of engine cylinders seems likely. A further possibility, for introduction into America, seems to Mr. Sergardi to be a two-passenger car of small horsepower and short wheelbase, to be sold at a cost much below that of the present low-price car.

Main Features of the Discussion

In commenting upon the points brought out in Mr. Sergardi's paper, David Beecroft said in part that the future small-car must be large enough to meet the requirements of the American family which is, each year, making greater and greater use of the highways in this Country. He remarked the fact that the highways are being traveled by an increasing number of people who represent the working and the agricultural classes and he believes that these people will demand a reasonable measure of comfort from the cars they buy, regardless of the size of the car. He thinks that provision for carrying baggage should be made on such a car and buyers will demand a car practically equal to the larger cars as to speed, acceleration and braking efficiency. He stated his belief also that a uniform rate of acceleration is very desirable, not only for small cars and for large cars but also for the various types of commercial vehicle.

Speaking of the tendency toward greater car-speed, he mentioned an instance in which a sign placed on a certain highway within the confines of New York City directed drivers who were traveling at less than 35 m.p.h. to pull over to the curb, and said no person will be content with a small car that will compel him to "pull over to the curb." He remarked further that if the minimum car-speed is say 35 m.p.h. as in the foregoing instance, this minimum easily may be 45 to 50 m.p.h. in the near future.

In Mr. Beecroft's opinion, it is futile to hope for the success of a tread that is less than the standard, mainly because of the conditions of the roads in many parts of the Country in winter. In conclusion, he said that the American buying-public will not be content with any car-performance that does not measure up to the legal limits within which the cars can be operated.

(*Concluded on p.* 312)

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

FUEL RESEARCH SUMMARIZED

Fuel-Volatility, Oil-Dilution and Engine-Starting Major Subjects Studied

At the request of the American Petroleum Institute and this Society, Dr. H. C. Dickinson[1], chairman of the Research Committee, prepared a summary of the execution and achievements of the Cooperative Fuel Research since its initiation. This project consists of an investigation carried out at the Bureau of Standards under the auspices of the American Petroleum Institute, the National Automobile Chamber of Commerce and this Society. The summary prepared by Dr. Dickinson was presented at the Seventh Annual Meeting of the American Petroleum Institute and at the 1927 Annual Meeting of this Society.

In the summary the objects and results of projects undertaken in the joint investigation of automotive fuels are stated briefly. Conclusions drawn from a series of summer and winter road-tests by the Bureau of Standards of four fuels covering the practical range of volatility and burned in four different representative types of passenger car and from a series of similar road-tests conducted by two groups of 10 or more automobile companies with groups of from 4 to 12 cars each are given. Results of these surveys are said to show that economy dictates the use of as heavy a fuel as practicable but that crankcase-oil dilution and the difficulty of starting engines set practical limits to the heaviness or volatility of the fuel that can be used.

Therefore a program of investigation of oil dilution at the Bureau of Standards covering 2 years was undertaken and carried through. Deductions from the results of this work are enumerated and indicated measures to be taken to reduce dilution are listed. Collection and analysis of about 600 samples of diluted oil from the crankcases of cars operated in widely separated parts of the Country resulted in the development of two satisfactory methods of measuring crankcase-oil dilution, one of which is now used extensively while the other is being studied by several refineries and promises to be of considerable value.

A third major project that has been under way for more than a year is the investigation of engine starting as affected by fuel characteristics.

The underlying object of the entire program is to provide technical information needed to maintain the best practicable adjustment of the automotive engine and its fuel, each to the other, to obtain maximum over-all efficiency. Tangible results so far obtained seem amply to justify the work. Of even more importance may be the intangible results, such as the noticeably improved relations between the automotive and the petroleum industries and stimulation of fuel-research work by both industries.

The full report prepared by Dr. Dickinson follows:

The Cooperative Fuel-Research to Date

The cooperative fuel-research project was begun in 1922, when the automotive and the petroleum industries, through the National Automobile Chamber of Commerce and the American Petroleum Institute, provided a joint fund to be administered by the Society of Automotive Engineers for the prosecution of a research program at the Bureau of Standards. This program was placed under the general supervision of a joint steering-committee which has met frequently, authorized the general lines of work and passed upon the results before they were made public.

The first project undertaken under this joint arrangement, was to determine what is the *best gasoline* as regards volatility, considered on a broad economic basis; that is, *what grade of gasoline affords the maximum number of car-miles of transportation per barrel of crude oil used in its production.*

This question obviously could not be answered in the laboratory alone. It did not suffice to know how much more efficiently an engine could be run under ideal conditions in the laboratory on one fuel than another. It was necessary to know also how much more of one kind of fuel than of another the average car used on the road. This difference multiplied by the total number of cars in the Country might be expected to give the difference in National consumption of the two fuels. This figure and an estimate of the relative cost of the two fuels would answer the question as to which was the more economical as regards car operations and national resources.

How the Problem Was Attacked

The problem was attacked from two angles: First, four test-fuels, designated as *A*, *B*, *C*, and *D* and covering the practical range of volatilities, were specified for experimental purposes and made up in quantity by two different refineries, one in the Mid-West and one in the East. For the first angle of attack four types of passenger-car were selected that together represented about 75 per cent of the total number of cars in service in the Country at that time. One used-car of each type, which had been run from 1 to 2 years, was secured for a test program at the Bureau of Standards. The test cars, which were thus typical of those in service, were put through a series of tests for average fuel-consumption with each of the four different fuels under road conditions. The details of this program were considered carefully by the steering committee as well as by the Bureau of Standards staff to assure that the results would be truly typical of average driving-conditions. The program consisted of one series of tests in summer with all four cars and another complete series in winter-time with two of the cars.

The second angle of attack comprised a cooperative project between 10 automobile companies and the Research Department of the Society. Two separate road-test programs were laid out by the Research Department, one to represent summer operating-conditions and the other winter conditions of operation. Each of the companies selected a group of from 4 to 12 cars driven in regular service by members of its staff and purchased enough of the four test-fuels to supply the group of selected cars for at least 4 weeks. Each of these cars was supplied with one of the experimental fuels for 1 week, another for the second week and so on, according to a carefully prearranged program designed to average-out weather conditions and individual differences. Thus each series of tests for each company lasted 4 weeks. The total number of car-weeks was about 250 for the summer series. This entire program was repeated during the succeeding winter under cold-weather conditions, by a somewhat different group of companies.

These tests were supervised entirely by the engineering or the research departments of the several companies and the results were reported to the Society on forms prepared for the purpose. The results were then summarized by the Society's Research Department.

[1] M.S.A.E.—Physicist and chief of the division of heat and power, Bureau of Standards, City of Washington.

Deductions from Tests with Four Fuels

Thus two distinct projects, each covering both a winter and a summer schedule, were carried out, one by the Bureau of Standards under road conditions but with laboratory precision, so to speak, and the other by 10 or more individual companies making use of about 150 cars, which were driven by their owners in usual service. When the results of these four independent series of tests had been collected, the following conclusions were reached:

(1) Within the range covered by the test fuels the number of ton-miles per gallon is independent of the fuel volatility; consequently, the heaviest fuel is the most economical (Federal specifications for motor gasoline were modified on the strength of this result)

(2) Gasoline consumption is somewhat greater in winter than in summer

(3) Dilution of crankcase oil is consistently greater the heavier or less volatile the fuel is

(4) Dilution of crankcase oil is much greater in cold than in warm weather

(5) Small differences in initial volatility of the fuel have a large effect on engine starting

(6) Effect on the starting performance of an engine is the characteristic of a fuel that is most readily noted by the driver

From this survey it was concluded that economy dictates the use of as heavy a fuel as possible but that a practical limit in this direction is set by the dilution of crankcase oil and the difficulty of starting.

Conclusions Drawn from Dilution Tests

The steering committee then decided to make a study of crankcase-oil dilution. Data were already at hand from the analyses of samples secured in the course of the tests already mentioned. A carefully arranged program on this subject of dilution, covering nearly 2 years of work at the Bureau of Standards, led to the following general conclusions:

(1) Dilution depends upon the temperature of the engine cylinder-walls and upon the volatility of the gasoline, taking the 90 per cent point on the distillation curve of the American Society for Testing Materials as an index of volatility

(2) Dilution increases with richness of the air-fuel mixture

(3) Dilution decreases with higher temperature in the crankcase and particularly when the crankcase is ventilated

(4) Dilution does not increase indefinitely but tends to reach a definite percentage which depends upon the average operating-conditions

(5) This equilibrium dilution is not much affected by air temperature, piston and ring fit or oil viscosity

Therefore to reduce dilution:

(1) Operate with high cylinder-wall temperature

(2) Reduce the time required to reach normal operating-temperature

(3) Always use as lean mixtures as practicable

(4) Operate with high oil-temperature

(5) Ventilate the crankcase

As the Bureau's work on fuel consumption was supplemented by the road service-tests mentioned, likewise the laboratory results on dilution were supplemented by analysis of about 600 samples of used crankcase-oils. These samples were collected according to a carefully prepared schedule from typical makes of car distributed throughout the Country. The laying-out of this schedule and the collection of samples were undertaken by the Research Department of the Society and the results have been summarized and published in The Journal, as have been all the results outlined in the foregoing part of this review.

In the course of this work two satisfactory methods for measuring crankcase-oil dilution were developed, one of which is now widely used and is under consideration by the American Society for Testing Materials for a tentative standard.

A distillation test for gasoline has been devised which duplicates the conditions in an engine manifold. This method is being studied by several refineries and promises to be of considerable value.

The third major project, that of engine starting as affected by fuel characteristics, has been under way for more than 1 year and was the subject of a report that was presented at the Research Session of the Annual Meeting of the Society last month. The specific question proposed for solution was this, What changes in fuel would be needed to give the same starting ability in winter as in summer? The results to date answer this question and several others. They show that in the past motor fuels have been marketed without much regard to varying requirements for starting because the necessary knowledge of what was required for starting did not exist. They have shown how engine design might be modified to improve starting and what fuel characteristics are required for easy starting at any temperature. Easy starting implies a small number of engine revolutions necessary to start and means not only convenience to the operator but also economy in fuel consumption, saving in batteries and the minimum of dilution of the lubricant.

Means are now provided for the builders of motor-cars to specify fuels that will give reasonably good starting at any temperature and for manufacturers of fuels to produce these. Existing methods of testing are found adequate for this purpose with only minor precautions. Moreover, only a small percentage of the components of gasoline are involved in starting ability at low temperature, where it is most important; thus the economic problems involved are probably less serious than might have been expected.

It may not be longer necessary to use fuels that, like some of those tested, will give only 20 starts per gal. at 32 deg. fahr. Others that differ only a little from them will give 100 starts.

The foregoing presents very briefly the outstanding tangible results of this joint research. The underlying object of the entire program, expressed concisely, is to furnish both the automotive and the petroleum industries, so far as possible, with the technical information needed to maintain the best practicable adjustment of the engine to the fuel and the fuel to the engine with a view to maximum over-all efficiency.

These two industries have contributed jointly to date on an equal basis about $45,000, of which about $35,000 has been expended. More than $40,000 has been contributed by the Government.

Automotive and Petroleum Industries Brought Together

While the tangible results seem amply to justify the work, some of the intangible results may be even more important. When this work was initiated in 1921, the automotive and the petroleum industries were inclined to place full responsibility each on the other for any lack of adjustment between fuel and engine. The first attempts at bringing representatives of the two industries together round a table for technical discussion led to endless debate and frequent recrimination, but a marked change in the attitude of each industry toward the other has occurred since then.

Conferences between petroleum and automotive engineers concerning the joint research-program and open discussion of its results in the Annual Meetings of the Society of Automotive Engineers and of the American Petroleum Institute, doubtless have been an important factor in bringing about a better mutual understanding.

Moreover, conditions with respect to available motor-fuels and to fuel research have changed radically. A few years ago, so far as we know, scarcely a research laboratory in the petroleum industry was engaged in any systematic study of the qualities of gasoline in relation to engine performance; nor was the situation in the automotive industry much bet-

ter. Gasoline was then aptly defined by a prominent petroleum engineer as the cheapest hydrocarbon product that could be made to burn in an automobile engine, or in words of the same import. Today in contrast with that attitude, many if not most of the large producers of motor fuels are doing intensive work along this line. Fuels are being produced with direct regard to how they will perform in winter and in summer, as to knock value and as to crankcase-oil dilution. Automotive research-laboratories seem not to have contributed their fair share in the last few years to the solution of the fuel problem, although perhaps automotive engineers have done so, as some of the Society's best talent is now employed in this line of research in laboratories of the petroleum industry. Where the work is done matters little if only it is done.

This radical change that has occurred in the attitude of these two great industries toward each other and toward research on their common problems is, of course, the result of many causes, but there is little reason to doubt that the cooperative fuel-research program has had an important direct and indirect influence in bringing about the present satisfactory relation of the two industries toward the adaptation of fuels to existing engines and engines to available fuels for the public's benefit.

TRENDS IN PASSENGER-CAR DESIGN

Tendencies Evidenced at the Recent National Automobile Shows Analyzed

Because of his peculiar fitness by experience and splendid powers of analysis, Austin M. Wolf[2] was recently selected to prepare the article for the 1927 edition of the American Year Book on the recent engineering advances in design and construction throughout the automotive industry. Mr. Wolf has for many years been a most discerning and close student of automotive trends and tendencies, both in this Country and abroad. Only this continuous research in this particular field, brought uptodate by a thorough and painstaking inspection of new models and types, has enabled Mr. Wolf to prepare for the Research Department the following analysis of present-day trends and tendencies in domestic and foreign passenger-cars.

General Trends

Outstanding features of the Shows are the trend of the manufacturer away from single-model production into well-rounded lines with many body models, the small refined or adapted European-type car, the introduction of the single-sleeve-valve engine, the wide use of rubber as a load-carrying and power-transmitting element, lower-hung bodies, and the extensive use of color.

Engines

Though no decided changes have been made in engines, the process of refinement and care of detail are evident, making possible the trend toward higher car-speeds. Through the simple fundamentals of proper heat-dissipation and valve-cooling, thus relieving the lubricating system of ailments not relating directly thereto, one make has secured high sustained power-output.

A greater number of eight-cylinder engines are seen, particularly small ones, and bores have been slightly increased all along the line. Compression ratios now peak at 5.27 to 1.0, this being made possible through the relative non-detonating characteristics of the small cylinder and the designer's certainty of the availability of special fuels in the field in which this particular engine will be operated.

Polished, not just machined, combustion-chambers have appeared, while inclined valves are used to make them more compact. Increase is noted in aluminum pistons with Invar struts, lighter cast-iron pistons, larger piston-pins, a solid center-portion to prevent rod-clamping distortion, and pins of the floating type. Chromium plating of piston-pins has been introduced not only for its wearing qualities but for its resistance to corrosion. Duralumin connecting-rods are more popular, as well as directly poured big-ends, thinner section of babbitt, smaller exhaust than inlet-valves, chrome-nickel inlet and silicon-chrome exhaust-valves, tulip-type valves in overhead construction, refined cam-ramp design, chilled cast-iron mushroom tappets welded to carbon-steel stems, and tappet cluster assemblies. Crankshafts have increased diameter and number of main bearings, and counter-weighting, as well as balancers and dampers, is considerably used, the last named often within the crankcase. Flywheel weights have been proportioned to car performance, separate forged-steel starter ring-gears are replacing the flywheel-cut teeth, and flywheel drain of possible clutch pilot-bearing lubricant leakage preserves the clutch linings. More engines have common distributor and oil-pump drive, unit fan and water-pump, full length water-jackets, and thermostatic water-control and air-draft. Stainless steel is used for pump-shafts. Direct cooling of valve-seats and spark-plug with the cylinder barrels in secondary or else thermosiphonic relation is noted. Many L-head engines have large water-ports to assure valve cooling, these ports establishing communication between the block and the cylinder-head and lying between the valves and the port face of the block.

Cold-weather and anti-scoring expedients are seen in direct cylinder-wall lubrication actuated by depressing the starter pedal, prevention of excessive oil-line pressure by an air-chamber ahead of the oil relief-valve and the use of a safety by-pass or an agitator for the pump. Greater use is made of interconnection of the throttle with oil pressure in non-Knight engines, and of cylinder-wall lubrication by the mating of a hole in the rod big-end with a duct in the crankshaft. The air-cleaner, oil-filter and rectifier are becoming universal; the crankcase ventilation, mentioned a year ago, has had a considerable following. Convenient draining is secured by the poppet-valve oil-drain. The bayonet type of oil gage is standard. Direct leads to the timing-train parts assure lubrication in this region. Sump baffle-plates prevent oil from surging away from the pump. The splash system has better-disposed dippers for high speed. Ground crankshaft oil-slingers assure oil-throw. Chain front-end drives predominate while single and double V-belt accessory drives are popular. Pressed-steel timing-case covers, and front and rear engine-supports—the latter sandwiched between the timing cover and block, and the block and bell-housing—are much used.

Mufflers taking the gas into the outer shell first; independent mufflers for the hot-spot branch; more effective hot-spots, sometimes dash-controlled; intensive manifold mixing; larger carbureters, and two carbureters for eight-cylinder distribution are seen. A convenient flywheel-timing inspection-opening is one about 45 deg. up on the front side of the bell-housing, avoiding removal of the floorboard if inspection is desired.

The introduction of the single-sleeve-valve engine, together with the present fields covered by the double sleeve, again raises the question, Has the poppet valve reached its limitations? A reaction will ensue, as on the introduction of the original Knight; the proponents of the poppet-valve engine will not be found wanting. Knight-engine improvements involve the use of two eccentric shafts which enable shorter, and therefore much lighter, sleeves to be used, besides reducing over-all height and supplying under heavy duty additional oil-supply to cylinder-walls and sleeves.

Various forms of rubber-mounting of the engine in the frame have been developed, all serving to insulate the latter from engine vibration. A damper or brake is used in one instance to limit the amplitude of engine movement. Some have kept rigid rear-mounting with coil-spring front-supports. The laminated front-spring mounting is still retained by its maker.

Clutch and Transmission

Throwout shafts below center and single-plate clutches predominate, with a flexible element often incorporated in the driven member. Multiple-disc clutch drums have openings for riddance of abraded material. The full-depth involute tooth has replaced the stub for quiet action. Lower

[2] M.S.A.E.—Consulting engineer, New York City.

floor-heights have brought cover-plate and ball mounting closer to the shaft center. An internal-gear reduction for third speed is of interest in view of the possibility of lower axle-ratios, pending the development of a quiet, easily manipulated four-speed transmission.

Universal-Joint

In the metallic type of universal-joint, oil-lubricated joints are increasing. The rubber-disc type shows improved means of transmitting power and avoidance of critical disc-angularity between opposing spider-bosses. Rubber balls and blocks are used for cushioned drive. Greater precision in dynamic balance of propeller-shafts and brakes is adhered to. Spring-contracted, close-fitting grease-boots are used for the same purpose.

Rear Axle

The semi-floating rear-axle is the most popular, with independent wheel-thrust provision. Full-floating is reserved for the heavy types, with hub bearings mounted on an axle sleeve within and extending through the banjo housing similarly as heavy-duty truck-axle design. Oil and dirt sealing is more effective. Heavy ring-gears, straddle-pinion mounting and shim adjustment, three-bearing pinion-mounting, and wheel-bearing shim-adjustment are increasingly popular. Wider-than-standard tread allows wider rear-seat cushions. Underslung worm and hypoid gears have made lower body-heights possible. Brake-anchor castings are being replaced by plates and only minor castings are used, the wheel bearing and gear carriers being the only dominant ones. Plain welded-on pads have taken the place of the former awkward spring-seats. An end bolted-on construction is in vogue, taking in brake enclosure plate, anchorage, bearing housing and seal, as a result no doubt of the arrival of the brake specialist, apart from the axle maker.

Brakes

Four-wheel brakes have been extended to light cars, and the mechanical type has increased in number. Emergency hook-up with the rear shoes is popular. External brakes predominate. Vacuum-operated brakes, high-carbon drums, greater circumferential drum utilization, self-centering cams, cam substitutes, and the freer use of serrated joints and oilless bearings are evident. Copper lines in hydraulic systems are sheathed in steel-wire covering for protection and sometimes placed outside the frame for cooling and isolation from muffler and under-the-body heat.

Front Axle

The reversed-Elliot type of knuckle is practically standard on front axles, front-wheel brakes favoring this. To withstand braking stresses, better proportioning exists between the spring-seat and knuckle. The king-pin angle is pretty well standardized at 6 or 7 deg.; some, however, retain vertical pins with brake equipment. Friction devices are often incorporated in or actuated by the rod mechanism to dampen shimmy.

Wheels and Tires

Disc wheels blend well with low lines and are popular. Metal felloes for small-sized rims accentuate how little wood is left in a wood wheel. The wire wheel has staged a comeback. Eighteen inch rims are in use. Tire-valve weights are balanced and individually adjustable felloe-mounted weights also are used to secure perfect dynamic balance to combat incipient shimmy. Balloon tires are universal but the six-ply construction has fought the four-ply to about an even basis. Recommended tire-pressures have been raised slightly.

Suspension

Rubber as a cushion between springs and frame is found, either in compression or in the form of rubberized fabric. The latter aims to preserve the natural steel-spring characteristics. Front springs are especially built to withstand braking stresses and in some cases to hold the front axle in position should main-leaf breakage occur. Front-spring front-end shackles have increased. Better coordination exists between springs and rebound-control mechanisms.

Frames

Stiffer frames, double-drop construction and increased use of tubular cross-members for torsional rigidity are seen. One design incorporates eight cross-members, seven tubular and one channel. Resilient rear engine-supports call for a new cross-member at this point. Real thought has been given to built-in bumper and shock-absorber mountings. One maker has installed a truss under and riveted to the side-rail, consisting of a channel section with tapered ends.

Control

High steering-gear reduction, wood steering-wheels and spokes and accessible gearshift levers are noted. Increased use is seen of the instrument-board-mounted emergency-brake handle. Spark and throttle levers are nearly all above the wheel, with the headlight switch often similarly located. Of interest is a floorboard-mounted switch below the clutch pedal; also a switch with lighting and ignition combinations whereby parking with bright lights is impossible. The worm-and-sector type of gear is being replaced by an hour-glass worm actuating a co-meshing roller on the steering-shaft lever. Pedal centers mounted on the transmission case accentuate compact powerplants and large pedal-radius.

Equipment

An increasing use of coincidental locks, particularly of the ignition-steering type; the board-mounted number-plate as an anti-theft measure; dash gasoline-gages; the artistic grouping of instruments into indirectly illuminated panels; and central lubricating systems with ingenuous methods of flow control and actuation is noted. The single-unit starting and lighting system is now extinct; high central distribution-mounting is general; double interrupters for six and eight-cylinder engines are increasing; and the double-filament bulb is used to a considerable extent, sometimes with an auxiliary parking lamp. A new lamp is shown, characterized by its wide beam-spread and no need for bulb-focusing adjustment. Battery and tool boxes, partly built into the front fender are in increasing favor. The hot-air type of heater and the battery-level tell-tale lamp are now seen as standard equipment. A new bumper utilizes a rubber air-cell member as a support for and cushioning element between the usual steel bars.

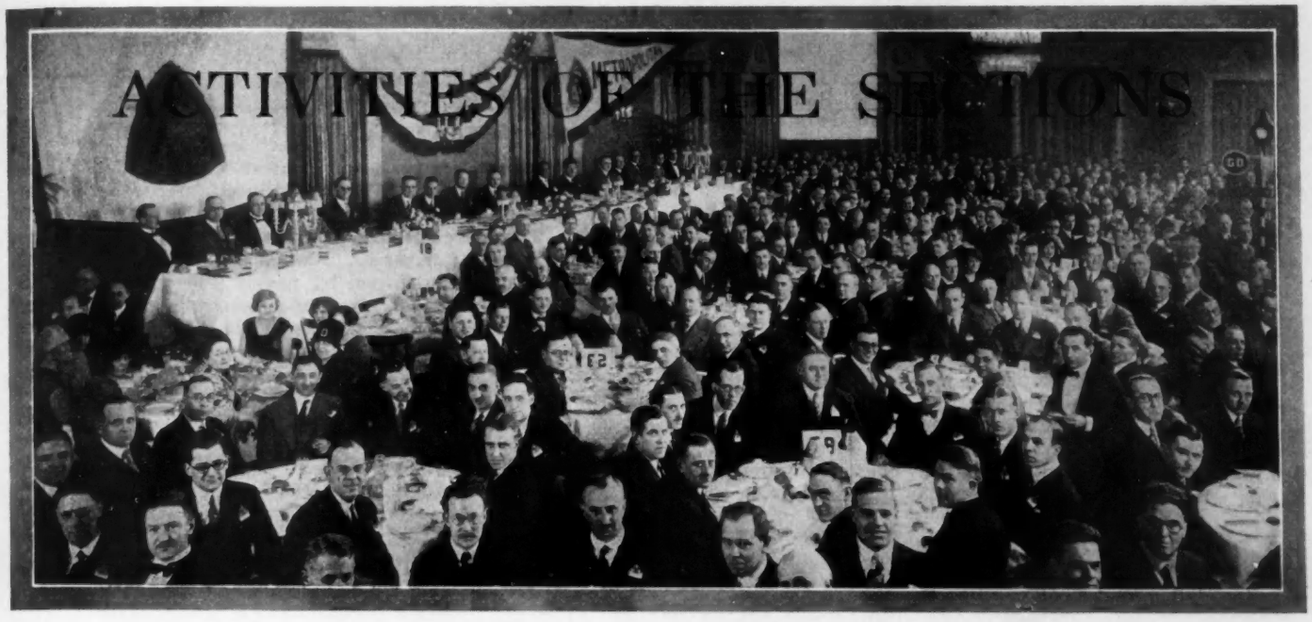
Sheet Metal and Body

Deep-crown fenders, one-piece fender crowns and aprons, polished radiator shells, and cap ornaments are in vogue. Hoods show a variety of horizontal, angular and grouped louvers, while flared top panels and improved fastening means are seen.

Bodies are built more substantially to withstand increased stresses due to high car-speeds and four-wheel brakes. The leather-covered, flexible wood-frame body is now seen and realization of its light weight is emphasized by swinging a door open and shut. Non-shatterable glass; narrow corner-posts, sometimes with a slight forward curve near the top; D-shaped rear windows; well-rounded rear quarters, in one case with considerable forward tilt of the major back portion; curved roof-lines; remote lock-control often combined to act as a pull-to; the gain of soft leather for interior trim; walnut panels and garnishing moldings; and better ventilation are apparent. Rigid side-curtains on phaetons, English fashion, have been introduced.

Prominent belt beadings extending back from the radiator, and reveals in contrasting color or raised beadings around the windows, are used. Reveals with deep lower panels give a low belt effect and the appearance of large windows. Vivid striping and two-color tones, above and below the belt, predominate, with superstructure, fenders, splashers, and wheels often differently treated, thanks to production possibilities with pyroxylin finishes. Disc wheels harmonizing with the predominating body color are popular. It is

(*Concluded on p.* 254)



IMPROVEMENTS IN 1927 CARS

Company Engineers Review Them in 5-Min. Talks at Metropolitan Section Meeting

High-spots in interest that made the Automobile Show dinner-meeting of the Metropolitan Section on Jan. 10 the most enthusiastic meeting the Section ever held were

(1) An attendance of 470, the largest number ever present
(2) Announcement that the Section now has more members than any other in the Society except the Detroit Section
(3) A short talk by President-Elect J. H. Hunt, of the Society, congratulating the Section
(4) Brief talks by delegates from Great Britain, Switzerland and Jamaica to the World Motor Transport Congress
(5) Summation of engineering trends by Austin M. Wolf
(6) Comparison of specifications of the Metropolitan Section composite car with the ideal American family car as specified by Mr. Wolf, winner of the composite-car contest
(7) Reviews of improvements in 10 makes of car by the company engineers
(8) A good dinner, music and a "bag of tricks"

The east ballroom of the Commodore Hotel was packed to capacity with 50 tables and 470 diners when the dinner started at 6:30 p. m. During its progress each diner was presented with a large envelope of souvenirs. With the opening of the packages the clatter of Hindu sticks added to the din of the jazz orchestra, and paper airplanes sailed promiscuously from table to table.

Hunt and Foreign Delegates Heard From

When the technical meeting was called at 8:30 by Chairman F. K. Glynn, he read a telegram from President T. J. Litle, Jr., of the Society, expressing disappointment that he was unable to arrive in New York City in time to attend the meeting. J. H. Hunt, president-elect, when announced, said that the planned program deserved all the attention that any audience should give to a program during show week and he would not interfere with it but wanted to say, as Chairman of the Sections Committee for 3 years, that it looks as if the Detroit Section would have to get on its toes to match the Metropolitan Section on attendance and on percentage of Society members in its territory who have joined the Section.

Col. J. Sealy Clarke, past-president of the Society of motor Manufacturers & Traders of Great Britain; John Badertscher, of the Automotive Dealers Association of Switzerland; and George N. Penso, of the Imperial Association of Jamaica, delegates to the Third World Motor Transport Congress, followed with brief remarks. Mr. Badertscher mentioned that he had been disappointed not to see any passenger-car at the automobile show equipped with vacuum brakes. Citroen, the largest French car builder, has adopted airbrakes and some of the larger European car-builders are now testing vacuum brakes.

Mr. Penso made a humorous explanation of how he was inveigled to become a guest at the meeting and "led to the slaughter" at the speakers' table. On his left, he said, he was introduced to Mr. Wolf and said to him, "Mr. Wolf, this is the last of me." "But he was very kind to me," added Mr. Penso, "and said, 'I have been domesticated.'" When asked to come to the dinner the thought uppermost in his mind, Mr. Penso remarked, was that some of the engineers might tell him there was some possibility in a suggestion put out by him that engines taken out of old used cars might be used in some way for domestic purposes.

To Hold Student Engineers' Meeting Feb. 16

At this stage of the program Chairman Glynn announced that in furtherance of the Section's sponsoring of a student engineers' meeting the students from engineering schools in and around New York City have been invited to attend a meeting the evening of Feb. 16 at the Fraternity Club Building, 38th Street and Madison Avenue. The topic is to be Man-Power in the Automotive Industry, and the speakers arranged for are J. H. Hunt, who will talk on Research and Design; John Younger, on Production; J. F. Winchester, on Operation; and David Beecroft, past-president of the Society.

The February monthly meeting of the Section is to be held the evening of the 17th, and the subject is Motorcoaches. R. N. Graham is to be the speaker.

Wolf Summarizes Engineering Trends

Trends in engineering as revealed at the New York Automobile Show that opened the Saturday before the Metropolitan Section meeting were summarized, after the talks by the company engineers were concluded, by Austin M. Wolf. He was selected for the task because of his recognized power of observation and his analytical ability and also because he was the winner of the Section's Composite-Car Contest, which had been conducted in the months of October, November and December by questionnaires filled out and returned by Section members. In recognition of this victory the prize offered, a handsome brief-case, was presented to him at the

TABLE 1—LEADING COMPETITORS IN COMPOSITE-CAR CONTEST AND POINTS WON BY EACH

Place	Contestant	Chassis, Points	Engine, Points	Body, Points	Total Points
1	Austin M. Wolf	20	32	18	70
2	L. Ochtman, Jr.	18	35	16	69
3	L. T. Weiss, Jr.	15	38	14	67
4	H. S. Durland	18	34	14	66
5	F. E. Richardson	13	36	15	64
6	J. C. Morrell	18	30	15	63
	Harold Nutt	15	33	15	63
7	Marie Luhring	20	28	10	58
8	C. M. Aument	17	27	13	57
	F. Leslie Jacobus	17	30	10	57

meeting by George A. Round, a member of the Composite-Car Committee.

Mr. Wolf gave a very comprehensive summation of the new developments and trends, which was listened to attentively and made a marked impression. The information given in this analysis, together with similar information on present European practice, will be found set forth in orderly arrangement in the Automotive Research section of this issue of THE JOURNAL.

COMPOSITE-CAR CONTEST AND ITS RESULTS

Results of the composite-car contest were then announced by Chairman Glynn as in Table 1. Specifications of the composite car are given in the first column of specifications in Table 2. These are the specifications that for each item were given the largest number of times in the questionnaires that were filled in and returned by nearly 150 engineers. Returns were accepted only from members who attended each of the regular monthly meetings of the Section in each of the 3 months. In the second parallel column are given the specifications for an ideal American family car as submitted by the winner of the contest by the narrow margin of 1 point. As a matter of added interest, a third column gives the composite specifications of American cars for 1927, as compiled by Donald Blanchard, of the Chilton-Class Journal Co., and are from 75 to 90 per cent complete. Where pos-

TABLE 2—COMPARISON OF SPECIFICATIONS OF METROPOLITAN SECTION COMPOSITE CAR, WINNING CAR AND TYPICAL AMERICAN CAR

	Composite Car	Winning Car	Typical Car
Chassis Specifications			
Frame			
Material	Pressed Steel	Pressed Steel	Pressed Steel
Axles			
Wheelbase, in.	121	120	121
Section, Type	I Section	I Section	I Section
Front-Axle End, Type	Reversed Elliott	Reversed Elliott	.....
Minimum Road Clearance, in.	9	10	9¼
Live Axle, Type	Full Floating	Half Floating	Half Floating
Final Drive	Spiral Bevel	Spiral Bevel	Spiral Bevel
Gear-Ratio	4.60	4.75	4.70
Propulsion through	Springs	Springs	Springs
Torque through	Springs	Springs	Springs
Springs			
Shackles	Rubber	Rubber	Metal
Front Springs, Type	Half Elliptic	Half Elliptic	Half Elliptic
Rear Springs, Type	Half Elliptic	Half Elliptic	Half Elliptic
Wheels			
Type	Artillery	Disc	Artillery
Tires			
Type	Balloon	Balloon	Balloon
Size, in.	31 x 5.25	32 x 6.20	32 x 6.00
Brakes			
Foot, Type	Internal, Four-Wheel	Internal, Four-Wheel	External, Four-Wheel
Application	Direct, Mechanical	Direct, Mechanical	Direct, Mechanical
Hand, Type	External, Drive Shaft	External, Drive Shaft	External, Drive Shaft
Steering Gear			
Type	Cam and Lever	Cam and Lever	Cam and Lever
Minimum Diameter of Turning Circle, ft.	34.0	40.0	37.5
Clutch			
Type	Single Dry Plate	Single Dry Plate	Single Dry Plate
Clutch Brake	Yes	Yes	.....
Gearset			
Location	Unit with Engine	Unit with Engine	Unit with Engine
Number of Forward Speeds	3	3	3
Low-Gear Ratio, to Wheels	9.0 to 1.0	15.4 to 1.0	15.5 to 1.0
Universal-Joints			
Type	Metal	Metal	Metal
Chassis Weight, lb.	2,200	2,200	.....
Engine Specifications			
Cylinders			
Number	6	6	6
Bore, in.	3¼	3¼	3.36
Stroke, in.	5	5	4.61
Compression Ratio	5.10 to 1.00	4.75 to 1.00	4.62 to 1.00
Engine Speed at Maximum Brake-Horsepower, R.p.m.	2,800	3,000	2,750
Maximum Brake-Horsepower	60	75	66
Arrangement	Vertical	Vertical	Vertical
Cylinder-Head	Detachable	Detachable	Detachable
Crankcase			
Relation to Cylinders	Integral	Separate	Integral
Material, Upper Half	Cast Iron	Aluminum	Cast Iron
Lower Half	Pressed Steel	Pressed Steel	Pressed Steel
Points of Suspension	3	3	4

TABLE 2—COMPARISON OF SPECIFICATIONS OF METROPOLITAN SECTION COMPOSITE CAR, WINNING CAR AND TYPICAL AMERICAN CAR (*Concluded*)

Valves			
Arrangement	At Side	At Side	.....
Head or Sleeve Material	Silchrome Steel	Silchrome Steel	Silchrome Steel[1]
Front-End Drive			
Type	Chain	Chain	Chain
Pistons			
Material	Aluminum	Aluminum	Cast Iron
Length, in.	4	4	.....
Distance from Pin Center to Top of Head, in.	2¼	2¼	.....
Number of Piston-Rings	4	3	3
Number of Rings above Pin	3	2	3
Complete Weight, oz.	20.0	22.0	26.8
Piston-Pins			
Diameter, in.	⅞	1 1/16	.....
Length, in.	3	3 1/16	.....
Location of Bearing	In Piston	In Rod	In Piston
Connecting-Rods			
Material	Alloy Steel	Alloy Steel	Carbon Steel
Center to Center Length, in.	10	12	9⅝
Bearings	Poured	Poured	.....
Crankshaft			
Crankpin Diameter, in.	2¼	2½	.....
Length, in.	2	1⅝	.....
Number of Bearings	7	4	[a]
Diameter of Front Main Bearing, in.	2¼	2¾	.....
Length, in.	3	3	.....
Offset	No	No	No
Counterbalances	Yes	Yes	No
Oiling System			
Type	Pressure to All Shaft and Connecting-Rod Bearings; Splash to Other Parts	Full Pressure to All Bearings, Including Wrist-Pins	Pressure to All Shaft and Connecting-Rod Bearings; Splash to to Other Parts
Pump, Type	Gear	Gear	Gear
Oil-Cleaner, Type	Distillator and Filter	Distillator and Filter	Distillator and Filter
Cooling System			
Type	Water	Water	Water
Circulation, Type	Pump	Pump	Pump
Pump, Type	Centrifugal	Centrifugal	Centrifugal
Radiator Core, Type	Ribbon Cellular	Ribbon Cellular	Ribbon Cellular
Thermostat	Yes	Yes	Yes, or Shutters
Water Capacity of System, gal.	4	4½	.....
Shell Material	Sheet Brass	German Silver	Pressed Steel
Fuel System			
Carbureter Size, in.	1¼	1¼	1½
Fuel Feed, Type	Vacuum	Vacuum	Vacuum
Air-Cleaner, Type	Inertia	Centrifugal	Inertia
Electrical System			
Current Source	Battery	Battery	Battery
Spark Control	Hand and Automatic	Hand and Automatic	Hand and Automatic
Starter Engagement	Bendix	Bendix	Bendix
Battery Voltage	6	6	6
Battery Capacity, amp-hr.	120	120	112
Body and Equipment Specifications			
Body			
Type	Sedan	Sedan	.....
Number of Doors	4	4	.....
Frame Material	Metal and Wood	Metal and Wood	.....
Covering Material of Panels	Steel	Steel	.....
Rear and Quarter Sections	Steel	Steel	.....
Upholstery	Broadcloth	Broadcloth	.....
Top	Rubber-Coated Fabric	Rubber-Coated Fabric	.....
Finish, Type	Pyroxylin	Pyroxylin	.....
Windshield, Type	One-Piece	One-Piece	.....
Equipment			
Snubbers or Shock-Absorbers Fitted	Yes	Yes	.....
Bumpers	Yes	Yes	.....
Trunk Rack	No	Yes	.....
Windshield Wiper	Yes	Yes	.....
Car Heater	Yes	Yes	.....
Cowl Ventilator	Yes	Yes	.....
Motometer	Yes	Yes	.....
Dash Gasoline-Gage	Yes	Yes	.....
Cigar Lighter	Yes	Yes	.....
Locks Fitted	Door, Gearset and Spare Tire; or Door, Gearset, Ignition, and Spare Tire	Door, Gearset, Ignition, and Spare Tire	.....
Complete Car			
Weight, lb.	3,125	3,200	.....
Price	$1,626	$1,895	.....

[1] Exhaust-valves only.
[a] Of 65 six-cylinder engines, 26 have four main bearings, 26 have seven and 13 have three.

THE FRAME OF THE CHRYSLER CAR

The Brake-Lines Are Attached to the Outside of the Side-Rail So That Cooling Is Provided by the Air Currents between the Side-Rails and the Running-Board Splasher

sible, averages have been taken and in other cases the plurality in favor of one method of construction or material is adopted.

The most striking fact about this comparison is the close correspondence of the three sets of specifications, considering that the Metropolitan Section composite car represents the majority preferences of operating rather than designing engineers and the winning car the preferences of an individual consulting engineer. The "composite" and "typical" cars correspond in about 40 of the 60 points compared.

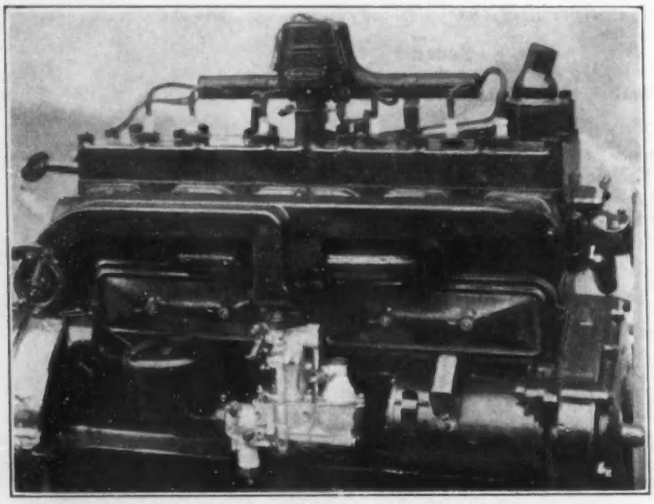
THE COMPOSITE AND THE IDEAL CONTRASTED

Comparing his ideal car with the composite specifications as compiled by the Metropolitan Section, Mr. Wolf explained the reasons for his preference where differences between the two appear. The difference of 1 in. in wheelbase, he said, could be gained, while retaining the same body and engine length, by moving the accessory drive to the front of the engine and placing the radiator farther forward. The 10-in. road clearance he prefers to 9 in. because the average American loves nature and wants to drive on back roads. He specified semi-floating live axles as against the full-floating type because the trend of practically all cars is toward the former and the full-floating axle can be used only on heavy cars. Spiral-bevel gears were named because he believed the head of a person in a car should not be much lower than in the normal standing position so that the driver's judgment will in no way be changed. Even with spiral-bevel gears a design can be worked out to give a reasonably low body-height. A gear-ratio of 4.75 to 1.00, he believes, will give suitable climbing ability and acceleration, in the type of car specified, for the prevailing topography of the Country.

Rubber is specified for the spring shackles because cars have been much too rigid. As American owners will clean their cars themselves frequently, disc wheels are preferred by Mr. Wolf, who favors them because they are easy to clean, are strong and present a good appearance. He said that he thinks the many corners and crevices now existing on cars might well be eliminated to make cleaning easier. The 32 x 6.20-in. balloon tires might be slightly liberal in size, but a little extra money expended in tire section is well worthwhile to absorb impacts at the source.

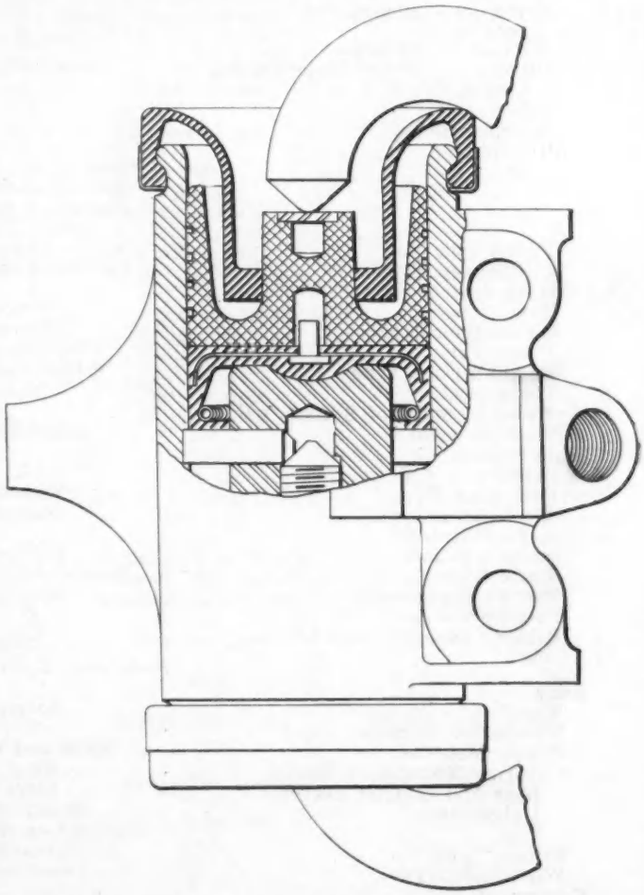
Four-wheel brakes, of internal type for cleanliness, are actuated mechanically, as Mr. Wolf believes this is the simplest method and tends to avoid excessive braking of the outer front wheel on turns. The minimum turning circle of the winning car is 40 ft. in diameter, whereas that of the composite car is given as 34 ft., but he thinks the latter figure was derived from drawing-board rather than from actual turning performance.

The low-gear ratio of 9 to 1 in the composite car is due to misunderstanding of the meaning of the questionnaire. The 15.4-to-1.0 ratio in the winning car means the reduction through the transmission and rear axle to the wheels, with a 3.25 to 1.00 reduction in the transmission.



THE ENGINE OF THE 1927 CHRYSLER CAR

A Special Feature of the Engine Is a Heat Control on the Exhaust-Manifold Which Is Operated from the Instrument Board. By Closing a Butterfly Valve at the Manifold Outlet, the Exhaust Gases from the Six Cylinders Can Be Forced around the Hot-Spot Portion of the Intake-Manifold



SECTION THROUGH THE WHEEL CYLINDER OF THE HYDRAULIC BRAKES USED ON THE 1927 CHRYSLER CARS

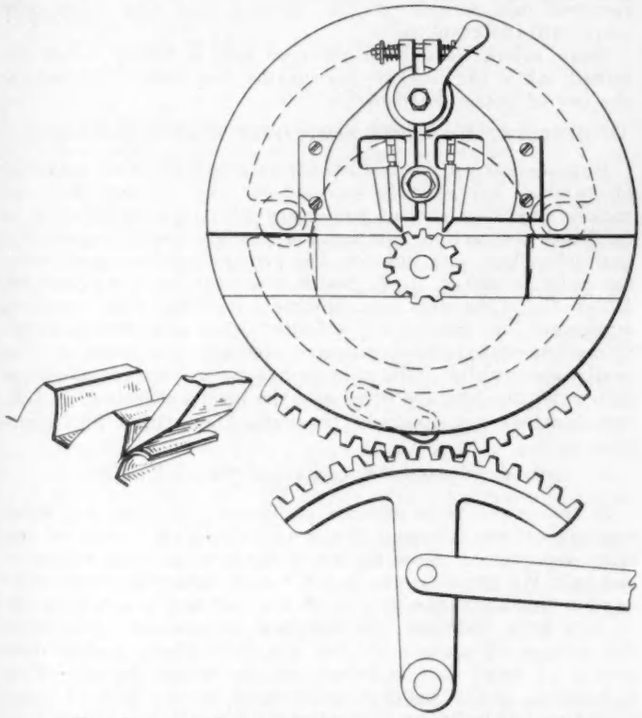
The Cups Used in the Wheel Cylinders and the Master Cylinders Are Molded To Receive a Small Close-Coiled Spring, the Ends of Which Are Joined, Thus Forming an Internal Expander To Keep the Cup Flanges Pressed against Cylinder-Wall

COMPRESSION ADAPTED TO PREVAILING FUEL

Engine compression in the winning car is 4.75 to 1.00 as against 5.00 to 1.00 in the composite car because the factor that determines compression-ratio is the quality of fuel that is distributed throughout the Country. The relatively high power of the ideal car, 75 hp., is not wonderful as it is only 1 hp. per cu. in. of piston displacement. The separate crankcase is desirable from a service point of view. Three piston-rings are preferred to four to reduce the largest component of friction losses. The 2-oz. greater piston weight is allow-

able to permit larger wristpins, which help to keep the engine quiet.

The 12-in. connecting-rod length as against 10 in. in the composite car Mr. Wolf thinks desirable to reduce the angularity of the rod. A counterweighted crankshaft with four main bearings, in preference to a seven-bearing shaft, was based on the dynamic loading, which is almost as great on



THE BARNES METHOD OF CUTTING AN INVOLUTE GEAR
In This Method the Finishing Cut Is Taken by a Shaving Tool That Is So Guided by Cams That the Direction of the Cut Is in Line with the Rolling Action of the Tooth, the Result Being the Production of a Perfect Involute Contour

the center bearing of a seven-bearing shaft as on that of a three-bearing shaft. More uniform load-distribution is obtained in a four-bearing shaft, he said. With increased engine-speed too much reliance must not be placed on crankcase rigidity.

The cooling-system of the winning car holds ½ gal. more water than that of the composite car, "which is a pretty good heat flywheel on hot days," said Mr. Wolf. A centrifugal air-cleaner is specified because it evens-out the suction impulses as the inertia-type cleaner cannot do.

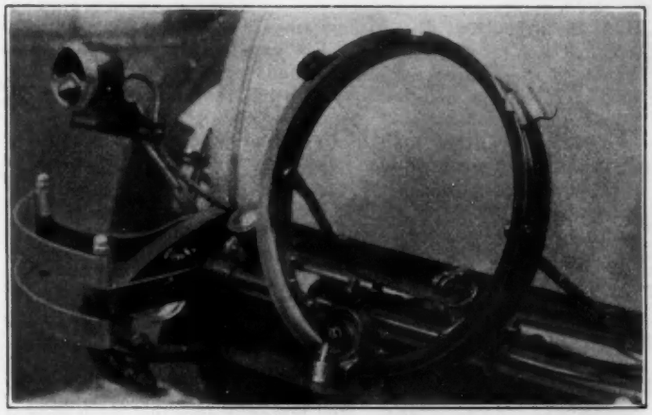
Equipment agrees on both cars except that a trunk rack is omitted on the composite car. "What is the average American going to do when he goes on his vacation?" asked Mr. Wolf.

His car is heavier by 75 lb. and the selling price is $269 more, but he thinks the increased advantages of his car will make the higher price possible from a selling standpoint.

Next was announced the 5-min. talks by chief engineers on the major improvements made by their companies on the cars for the present year.

TWO NEW CHRYSLER MODELS APPEAR

Two new Chrysler models are a light four-cylinder and a light six-cylinder car. The former has 3⅝ x 4½-in. cylinders, an impulse-damping device at the rear end of the engine, aluminum-alloy pistons, and a special spring cushion mounting at the front of the engine, resulting in an exceptionally smooth-running car of this type, according to H. T. Woolson, the Corporation's chief engineer. The six-cylinder Model 60 has a 3 x 4¼-in. engine, is equipped with four-wheel brakes, shock-absorbers, gasoline gage on the instrument board, and the units throughout follow the design of the Model 70 closely.

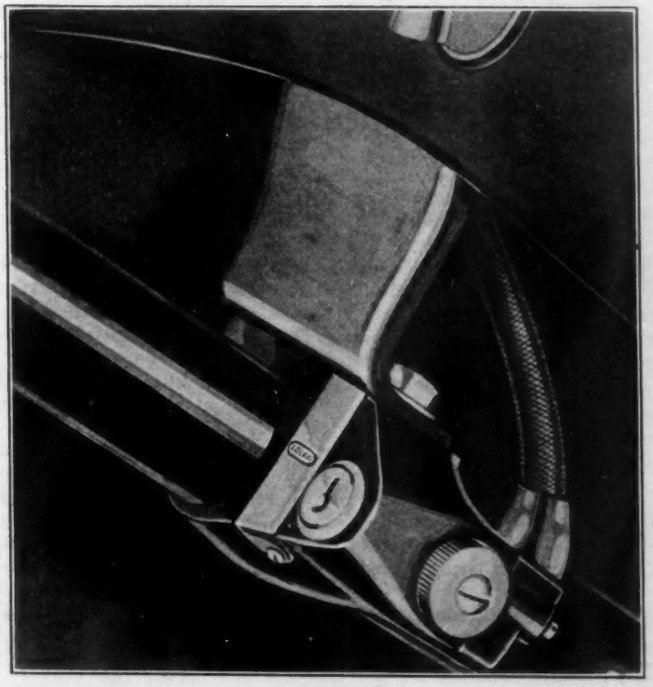


ONE OF THE NEW CHRYSLER TYPES OF TIRE CARRIER
This Carrier Is of Channel Section and Castings for Mounting a Satisfactory Lock Can Be Attached Readily

Tire diameters on three models have been reduced by the use of an 18-in. rim, thereby lowering the center of gravity and improving roadability and braking.

Several improvements in the hydraulic brakes that have been proved well worthwhile are in production, said Mr. Woolson, who illustrated these with lantern slides. Cups used in the master cylinders and wheel cylinders are molded to receive a small close-coiled spring, the ends of which are joined, thus forming an internal expander to keep the cup flanges pressed against the cylinder-wall. The brake-lines are attached to the outside of the chassis side-frames where air currents between the side rails and running-board splasher provide cooling. Another brake improvement is the development of hydraulic hose that has the minimum amount of expansion under liquid pressure in the system. In terms of foot movement, the expansion amounts to ½ in. for 100-lb. liquid pressure compared with a movement of 1½ in. for such hose as was used several years ago.

One slide showed the design of Invar pistons. The use of Invar was developed by the Chrysler engineers to take advantage of the practical freedom of this metal from expansion and contraction over a wide range of temperatures,



THE COINCIDENTAL TYPE OF LOCK USED ON THE MODEL 70 CHRYSLER

said Mr. Woolson, and to compensate for the expansion and contraction of aluminum. By careful design practically constant clearances are maintained between the pistons and cylinder-walls throughout the entire temperature range of the engine.

The heat-control manifold, manually operated from the instrument board, which has been in successful use for 1½ years, was also shown in a slide. By closing a butterfly valve at the manifold outlet, the exhaust gases from the six cylinders can be forced around the hot-spot portion of the intake-manifold, thereby greatly accelerating the heating of the engine, shortening the choking period and reducing possibility of crankcase oil-dilution.

New tire-carriers with locks were also shown. One is a channel-section carrier-ring to which castings can be attached for mounting a satisfactory lock. The other is a case-hardened-steel band surrounding the tire and secured to the tire ring by a lock. The latter is supplied as standard equipment on Model 80. Other devices mentioned were a rubber shock-insulator used on the same model to avoid spring breakage, improve riding-qualities and do away with shackle lubrication; a coincidental lock used on Model 70; an air-cleaner having no moving parts; and improved transmission lubrication.

A new method of gear cutting was shown, which has been in process of development at the Chrysler plant for several years and is known as the Barnes system. The finishing cut on a tooth is taken by a shaving tool that is so guided by cams as to produce a perfect involute contour, as the direction of the cut is in line with the rolling action of the tooth. This method has been used in production for more than 1 year and has, Mr. Woolson stated, been successful in producing teeth that as regards quiet running are equal to those produced by the gear-grinding machine.

Auburn Abandons Four-Cylinder Model

The four-cylinder Auburn model has been replaced by a six-cylinder model which is a redesign of last year's six-cylinder car with the weight reduced to get it into the price class of the four-cylinder car, said J. M. Crawford, chief engineer of the Auburn Automobile Co. With an engine of 185-cu. in. piston displacement, this car has a 121-in. wheelbase, in which respect the company is not following the industry, as it does not believe in a short wheelbase and small proportions even for light cars.

Demand for a faster car with smoother operation and better finish at a lower price led to the production of an eight-cylinder model to take the place of last year's six-cylinder car. The engine is of 2¾ x 4¾-in. bore and stroke, giving 260-cu. in. cylinder volume. Valves are inclined to reduce the size of the combustion-chamber and produce a high-compression, high-speed engine. At 3200 r.p.m. it develops 65 hp. and at top speed in high gear it turns at 4000 r.p.m. Front-end drive is by non-adjustable chain to the camshaft and double belt drive to generator and fan.

The next car in the price class is Model 8-88, which remains practically unchanged from last year except that the power of the eight-cylinder engine has been increased from 78 hp. at 2800 r.p.m. to 90 hp. at 3200 r.p.m., with a top engine-speed of 3900 r.p.m. This was accomplished by redesigning the exhaust-manifold, using a larger carbureter, raising compression and adopting Bohnalite pistons and duralumin connecting-rods. For firing at the higher speeds a four-lobe cam on the distributor with a duoble contact-breaker has been adopted in place of the eight-lobe cam. A Lanchester damper eliminates the torsional-vibration period. Hydraulic shock-absorbers are fitted and spring covers have been added to maintain more constant spring action. Tires of smaller diameter are fitted on 19-in. rims and tramping is prevented by balancing the wheels dynamically.

Bodies on all models have been changed in appearance by a new line of fenders and other sheet-metal equipment.

Buicks Made Nearly Vibrationless

Major improvements in the three Buick models are the counterbalacing of the crankshaft, putting a torsion balancer on the secondary shaft and mounting the engine on rubber supports to reduce vibration as much as possible, as reported by E. A. DeWaters, chief engineer of the Buick Motor Co. A crankcase ventilator has been provided and a thermostat in the water-line opens the valve so that the water heats to about 130 deg. fahr. in 2½ min. The combination of ventilator and thermostat drives out water condensation and removes considerable of the burned fuel that commonly seeps into the crankcase.

Body colors have been changed and a better finish obtained, while the interior appearance has been improved by the use of better hardware.

Chevrolet Embodies Simplified Standard Design

Engineering involved in an automobile that is an assembly of standard approved designs put out at a low cost does not include anything radical but is a matter of simplification to facilitate production and service, provide interchangeability and reliability, and improve the product without increasing the price, asserted H. F. Smith, engineer for the Chevrolet Motor Co. The new car, however, includes such standard equipment as air-cleaner, oil-filter and coincidental locks. Chromium-plated piston-pins are used and are believed to be really worthwhile. The chassis has been lowered, one-piece full-crown fenders are fitted and the pedals closed-in. S.A.E. specifications are followed throughout on steels and heat-treatment.

Five Marmon Models on Two Chassis

In the unavoidable absence of Thomas J. Litle, Jr., chief engineer of the Marmon Motor Car Co., Otis Lucas, of the sales department, made the hit of the evening with a humorous talk but nevertheless in his 5-min. time-allowance managed to "put over" the policies of the company in bringing out its new little Marmon. He said that the company is to have five groups of models on two chassis. These include two groups of small cars and three on the larger chassis. This is because of the belief that to exist in the face of competition a distributing organization must have a full line. In bringing out the little Marmon it was sensed that a demand exists in this Country for a small quality-automobile. This new car has a 116-in. wheelbase and a straight-eight-cylinder engine with 2¾ x 4-in. cylinders. The engine will turn up to 4200 r.p.m. Aluminum pistons with Invar struts are used. The manifold has siamese ports. Rear-axle drive is by hypoid gear, which assists in bringing the frame nearer the road surface. Wheels are 19 in. in diameter.

The larger chasis, however, will constitute the main reliance of the company.

New Stearns-Knight Eight-Cylinder Engine

An entirely new eight-cylinder sleeve-valve engine that departs from the conventional Knight-engine practice has been developed by the F. B. Stearns Co., and is used in the same chassis as the six-cylinder engine, said W. E. England, assistant chief engineer. This new engine has two eccentric shafts, one to drive the inner sleeves and the other, the outer sleeves. These shafts are supported on 17 bearings and one is driven by a non-adjustable two-point silent chain and the other, together with the accessory drive, by a Morse automatic adjustment. The design allows the sleeve pins to be as close as possible, reducing the leverage, and the sleeve rods operate almost directly under the sleeve lugs, which greatly decreases the sleeve-rod angularity. The inner and outer sleeve rods are the same length and the inner sleeve telescopes completely into the outer, thereby permitting reduction of the over-all length of both sleeves. As a result, the eight pairs of sleeves weigh 9 lb., or 33 per cent less than an equal number of sleeves of the six-cylinder engine. The crankshaft has nine 3-in. main bearings and is completely counterweighted. These counterweights weigh 50 lb., but the shaft, flywheel and clutch weigh only 8 lb. more than those of the six-cylinder car.

The compression-ratio is 4.7 to 1.0, and the engine develops

(*Concluded on p.* 273)

Vol. XX February, 1927 No. 2

The English Light-Car and Why

By Alan R. Fenn[1]

Annual Meeting Paper *Illustrated with* Photographs

ABSTRACT

ECONOMIC and other conditions that favored and practically forced the development of the light car in England, and the history of that development, are dealt with at length by the author. He recalls the light cars of the pioneer days of the automobile and then the putting on of weight about 1898 to increase reliability and riding comfort. He comments on the reaction that resulted in the advent of the cyclecar in 1911 and its quick demise because of its failure to perform satisfactorily. The keen interest of the public, however, indicated that a big business could be done in a light, efficient, cheap motor-car if it could be produced in a practical form. Genuinely light cars minus the crudities of the cyclecar then began making their appearance and quickly "caught on," due to the tax on gasoline, low selling prices, and automobile-club competitions that gave the public great confidence in these light vehicles.

Up to 1914 the light car, as distinguished from the cyclecar, was characterized by a two or four-cylinder engine of about 61-cu. in. capacity and was, as a rule, a two-passenger vehicle with not very generous equipment. It weighed about 1000 lb., had a speed of nearly 50 m.p.h. and consumed 1 gal. of gasoline to about 35 miles of normal touring-travel.

Following the World War, during which automobile production was almost entirely suspended, the tightness of money, a high automobile tax and the fact that the class of the public earning from $2,500 to $5,000 a year was hard hit, forced designers to exploit the small-capacity high-speed engine. Much had been learned about high-efficiency engines from aeronautic work during the World War, so in 1919 the light-weight low-horsepower general-utility family automobile made its appearance. It soon became a phaeton with a commodious body, and then an electric lighting and starting system, sliding front-seats, demountable wheels, and other equipment were added, which increased the weight. But the engine designer was able to keep pace with the demands on the powerplant without increasing the volumetric capacity much beyond 67.1 cu. in. and without sacrificing road performance. Compression-ratios were increased, crankshafts stiffened, and reciprocating parts lightened.

A certain clientele had become accustomed to large-car performance and luxury, however, and therefore, while in its earlier stages the light car became established purely on a price basis, the medium-price car and the higher-price specialized sports car appeared. The price range runs from $703.25 for the 7-hp. 91.5-cu. in. Austin to $5,000.00 for the complete four-passenger Martin phaeton. Three well-defined classes, as judged by engine dimensions, have engines of 91.5, 67.1 and 45.7-cu. in. piston displacement. Rated horsepower ranges from 7 up to from 12 to 24 and weights from 950 to 2240 lb. Maximum speed ranges from 48 to 67 m.p.h., and wheelbase from 105 to 108 in.

Specifications of the Morris-Cowley typical light-car are given by the author, who presents a table of performance of 10 English and Continental light cars and also a table of running costs aggregating $750 a year, or an average of 7½ cents per mile as against 6 cents per mile for railroad fare.

Success of the light car as a commercial product is indicated by profits made by the Morris company, which made a net of more than $5 000,000 per year for 1923, 1924 and 1925. Upward of 60 different makes of light car are either being built in England or imported from the Continent, and nearly two-thirds of the present production of passenger-cars in England is of light-car type.

Closed bodies are beginning to predominate, and Morris and Citroen are making extensive plans to adopt all-steel bodies. Weymann flexible bodies are coming into demand more and more.

Two interesting new developments that may be significant are the Trojan general-utility car having a two-cylinder two-stroke 10-hp. engine of 90.7-cu. in. capacity and selling at $625, and the Constantinesco, which has an engine of similar type but of only 30.5-cu. in. capacity and the Constantinesco transmission that eliminates all change-speed gears and clutches. The latter car can average 28 m.p.h. over ordinary roads with two passengers.

Six-cylinder engine development is evident, and another year is likely to see a large number of semi-light six-cylinder cars of a distinctly luxurious type.

WHEN I was invited to prepare this paper, it did not seem to me at first blush that it was fraught with anything like the difficulty that I have ultimately found, as not until one came really to consider the English light-car in a more or less abstract way was the real problem exposed of making clear to you the multitude of points that arise on consideration of the matter. The subject is so diffuse and such a very large number of factors should, strictly speaking, be introduced that it would take considerably more of your time than you would be prepared to give, I imagine, and might become very wearisome. After all it is customary, when reviewing the subject of a lecture or a paper, to draw up definite terms of reference so that attention may be confined without irrelevancy to the particular subject under consideration.

In this particular case the drawing-up of these terms of reference is, as I have indicated, an extraordinarily difficult matter. I am to speak to you upon the light car as it is known in England and Europe, but with special reference to the English automobile trade, and upon the way in which we view its possibilities from the English angle. Yet, at the outset I am free to confess that I cannot tell you in exact words precisely what I mean by a "light car." In the course of my paper I will make some references to the French aspect of this type of vehicle but I do not pretend that I have touched on the European Continental aspect. At the same time, notably in the development of the light car, French and German influence has played a considerable part, although without doubt the origination of this type of automobile certainly came from England.

In my Country when we speak of a light car we all know more or less the sort of vehicle to which we are referring. The expression, except in connection with competitions, is not susceptible of any exact definition. I think I should be right in saying that in America the

[1] Sunbeam-Talbot-Darracq Combine, London, England.

words "light car" undoubtedly mean something very different from what they convey on the eastern side of the Atlantic. I do not despair, however, and I am hopeful that during the course of this paper sufficient will have been said to indicate broadly what constitutes a light car in Europe.

It is, I think, an interesting fact that the development of the light car has been in a sense a reversion to type, and it is in fact a legacy from earlier days. But our light cars now are not so light as they once were; they are entitled to that name as lineal descendants of a race of automobiles that was in its time conspicuously light in weight. Without therefore attempting any close definition or confining the subject of this paper to a too close ambit I will endeavor briefly to trace its origin.

Origin of the Light Car

In this connection it is not too much to say that all, or nearly all, the pioneer motor-vehicles which laid the foundations, upon which the huge structure of automobilism has been built, were essentially light cars. Indeed many of them were extraordinarily light cars, showing a strong connection with cycle design. Not until the practicability of motor-vehicles had been fully demonstrated in or about the year 1898 did they begin to put on weight. This was for two reasons (*a*) the conspicuous unreliability of the earliest automobiles was such as to make them a subject for jest and it will be in the memory of some of us the many jokes and ridicule that were cast at the pioneers of the movement and (*b*) at the same time coupled with this unreliability was associated a degree of personal discomfort which to the present generation is unbelievable, more especially when it is viewed from the angle of the present day, with the silence, smoothness and luxury that rule.

It was clear, therefore, to the automobile designers of earlier days that reliability was the fundamental thing that they must go for, and it was largely accomplished by a general strengthening up all round, which in turn meant increases in power and in weight. The problem of improving comfort and accommodation could only be met in precisely the same manner.

If we review the progress that was made in the early days of automobilism both in Europe and America, we shall see that this progress was inevitably accompanied by a general increase in dimensions, and a general increase in weight. It was in the year 1902 that the German Mercedes Company produced a car which marked an epoch. It was immediately successful because it was comfortable, reliable and fast, and it exploited a form of design to which nearly all other automobile builders even until today have unanimously subscribed.

The Mercedes car was definitely a heavy car, and from the moment of its introduction almost all other cars tended to become heavier, stronger and more powerful. During this period of transition, there were still a certain number of light cars, but there can be no doubt that their value and utility were overshadowed by the virtues of the bigger vehicles, which were not only then coming into more extended private use but were demonstrating their roadworthiness in all the more important races and trials. It was but natural that this movement in the direction of greater weight, which of course involved greater cost, should have its reaction.

Rise and Fall of the Cylinder

About 1911, both in England and France, a very much lighter form of vehicle began to make its appearance. It was called the "cyclecar." It was supposed to embody the advantages of both the automobile and the motorcycle. As a matter of fact, it incorporated as a rule the disadvantages of both types.

In 1912 an Exhibition at Olympia was largely devoted to these cyclecars, and it may be said that most of the important motorcycle manufacturers and some producers of automobiles contributed their designs to it. With a single exception, the Morgan three-wheel runabout, which still has a vogue in Great Britain, those designs, ingenious and numerous as they were, proved utter failures. Most of them were as hastily withdrawn as decency permitted, for road performance had clearly shown that they were not yet in a fit state to be offered to the public. On the other hand, the latter had manifested a keen interest, which the eye of commerce was quick enough to perceive. The idea of a light, efficient, cheap motor-car could hardly fail to catch popular fancy, and it became obvious that if such a thing could be produced in a practical form there was very big business to be done.

The cyclecar was clearly doomed, but even as it tottered something better rose in its place. A few enterprising firms, both in England and in France, placed upon the market genuinely light cars which bore no relationship to the crudities of the cyclecar. They were in fact small cars in every sense of the phrase. Among their names may be mentioned, Singer, Standard, A. C., Swift, Star, Morris, Stellite and several others. They were not perhaps very wonderful vehicles but they were definitely "motor-cars" and they very quickly began to establish the vogue which their descendants still enjoy.

Why Light Cars Were in Demand

It is necessary here to point out some of the economic features that have made the light car so popular in Europe. At this time in England we had a tax on gasoline as opposed to the present form to which I will refer: in addition to which, gasoline was very much cheaper in the earlier days, so that the question of gasoline consumption was not a really primary point with the prospective purchaser. The great thing that he asked for was reliability, and many of the early efforts in the light-car market were brought to success almost on this ground alone. Under these circumstances, designers had a very much freer hand than they have today. Nevertheless, there was no doubt that the new and promising type that was being developed quickly caught on and many firms that had hitherto devoted their energies to the production of much larger vehicles now began to concentrate upon the smaller vehicle. An additional reason, I think, was the fact that at the time of which I am speaking considerable education of the public still remained to be done and, as usual, the price appeal was a very important factor in assisting the development of increased markets.

This was notably so in the case of the medical profession who, generally speaking, are men of moderate means and to whom first cost and running costs were a very vital consideration, even assuming that they were satisfied as to the reliability aspect. I mention this point as it will be appreciated that this particular profession was a most important one to attack in the earlier days as it provided one of the finest disseminators of propaganda and information about automobiles that could possibly be imagined, doctors coming as they do in contact with the whole of the population, and as these little vehicles improved in quality, performance and reliability so did the good news get spread.

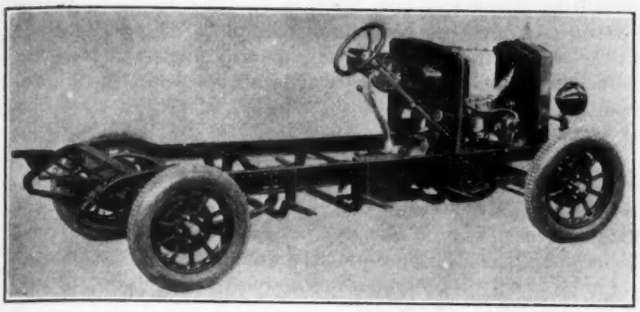


FIG. 1—THE CHASSIS OF THE 11-HP. MORRIS-COWLEY CAR

CLUB COMPETITIONS ESTABLISHED LIGHT TYPE

There has always been in England, as I imagine in America, a strong sporting element in the automobile movement, and a very large number of keenly run clubs sprang up, which reached considerable proportions at about this time, and therefore the coincidence of this new type of vehicle appearing, with the great enthusiasm among the sporting element, brought the light car into the British automobile firmament at a singularly opportune time. These clubs made a specialty of holding competitions and reliability trials, and the vigor with which they were conducted and the rigid regulations that were established, which prevented any faking of results, gave the public great confidence when vehicles showed themselves as thoroughly competent to undertake the extremely severe conditions under which many of these trials were run.

At this time, the bigger firms who were for the most part building the larger-size vehicles, had withdrawn their support from these competitions, as they had come to the conclusion that, so far as that type of vehicle was concerned, they were not assisting development, and furthermore the class of clientele to which they were catering was not the type to which the result of reliability trials appealed, and therefore the advent of the light vehicle offered an opportunity for enterprise in this direction to be re-awakened.

Practically from 1911 onward, until the World War broke out in 1914, all the open competitions in England, with the exception of the Tourist Trophy Race that was held in the Isle of Man, were concerned with light cars, and these gruelling tests that they received played an enormously important part in their rapid development. By this means the public were constantly stimulated and reminded by publicity and editorial matter of the reliability and desirability of the lighter type of vehicle, and although the development had reached a very considerable point of excellence up to the outbreak of World War, the fact remains that the type had not firmly established itself: in proof of which, during the World War only one make of light car, the Singer, was officially adopted by the British War Office for transport purposes, although I think it would be no exaggeration to say that far greater use, and consequent economy, could have been made of some of the light cars that were being built at that time.

CHARACTERISTICS OF PRE-WAR LIGHT CARS

Perhaps it may be opportune here to note that previous and up to 1914 the English light-car, as distinct from the cyclecar, had in general a two or four-cylinder engine of about 1 litre (61.0 cu. in.) capacity. It must be admitted that it still had various relics of the cyclecar influence in much of the detail design. The vehicle itself was, as a rule, a two-seater with a not particularly generous equipment. A typical case in point is the 10-hp. Morris of 1914, which had an engine of 1100 cc. (67.1 cu. in.) capacity and a total-vehicle weight, ready for the road, of approximately 1100 lb. It was a very competent little vehicle although it had nothing more than the absolute essentials in regard to its general make-up. Good examples would give a speed of nearer 50 than 40 m.p.h. on the level with a fuel consumption under ordinary touring conditions of about 35 miles per gal.

This brings us to the World War period, and during the whole of this time it may be taken as broadly true that the automobile industry of England, with the exception of a few firms, was entirely suspended. The industry concentrated entirely on aircraft engines, airplanes, fuzes, and small high-precision work of all kinds, but at the close of hostilities the impetus given to the light-car movement by economic conditions was most marked.

I neglect the period during which fantastic prices were paid for any kind of vehicle, new automobiles being unavailable because the factories had not changed over and got going on suitable designs and were also finishing off for a considerable period production for military needs; in addition to which, a very large amount of labor trouble of every kind constituted a grave handicap to development.

INFLUENCE OF CHANGES WROUGHT BY WAR

It was, however, very apparent that the demand for reliable and economic transport would be enormous. It must be remembered that the whole economic outlook in England, as in other countries, had completely changed, due to the lavish expenditure and the apparently large amount of money that was circulating; a huge number of people who had never thought of being able to own a motor-car had serious aspirations to do so; the public at large had realized the enormous importance and large contribution that the internal-combustion engine made among all the contending nations in the World War. Furthermore, thousands of men and women who had never known anything of an open-air life had learned its attractions, and the stimulus due to this reflected itself in the desire of the town dwellers to get far afield.

A not inconsiderable influence also was that due to the complete cessation of building of every kind, except factories; the difficulty of finding accommodation for transport of any sort was very serious; and the smaller

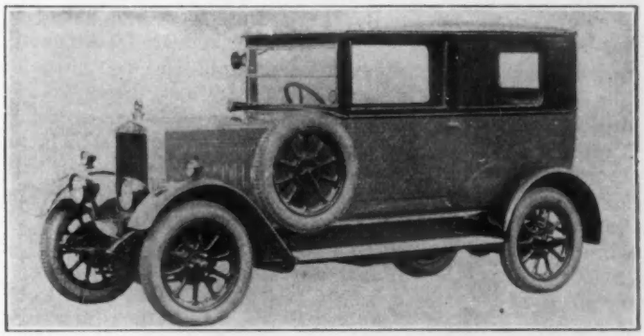


FIG. 2—THE MORRIS-COWLEY 11-HP. SALOON TYPE

The Specifications of This Car Are

Tread, in.	48
Wheelbase, in.	105
Over-All Length, in.	132
Over-All Width, in.	60
Road Clearance, in.	8¼
Tires	27 x 4.4

the vehicle the more attractive in many ways it became to a large number of people. This is still a considerable factor, so much so that some 2 years ago one of our largest manufacturers proceeded to put in production garages to sell with the car, of a type that did not require any skilled building assistance to erect. There is the additional fact of those living in the thickly populated areas of finding accommodation for their cars, rentals being largely based on the number of square feet a car occupies. A number of firms therefore who had never considered automobile production now turned their attention to it, and the reason for this state of affairs is not far to seek when the above is taken in conjunction with existing conditions.

Although, as I have indicated, the public came out of the World War with very much larger ideas than they went into it, the tightness of money soon became very marked, which forced a general grading-down of the better-off classes from the price standpoint, but a grading-up of those below them, due to the conditions engendered by war conditions. This may seem rather contradictory but the public that has been hit hardest by the war conditions are those earning from $2,500 up to $5,000 per year, they not having benefited to anything like the extent in proportion to what are known in England as the working classes and a bit beyond, and therefore personal economy was the order of the day.

Car Tax Based on Cylinder-Bore

A new form of tax was introduced, in which the levy upon the car owner was determined according to a formula, known as the Treasury Rating, which was arrived at by taking into account the bore of the engine and the number of cylinders, the horsepower resulting from the application of this official formula being taxed at the rate of £1 ($4.86) per hp. There was also the question of insurance which did then, as it now does, depend very closely upon the Treasury horsepower rating.

It will easily be understood that under these conditions English designers were encouraged, if indeed we may not say forced, to exploit the small-capacity high-speed engine. This taxation question has had a very large influence, as it is one of the first considerations taken into account by the prospect, and the method by which it is applied causes very serious difficulties and hardships both to the manufacturer as well as to the public.

The motoring public had quickly realized from prewar days that a so-called 10-hp. engine, capable of taking a light two-passenger car at 40 or 50 m.p.h. on the level, should be capable of dealing with a proportionately light four-passenger or family car if they were not asked to sacrifice too much in the performance required. As usual, necessity was the mother of invention, and the automobile industry speedily got down to giving a reply. Very much had been learned in many of the factories about high-efficiency engines from aircraft experience: a large amount of research work had been done by our Air Ministry, the National Physical Laboratory, and the Royal Aircraft Establishment at Farnborough, most of which was available to all who liked to ask for it. So in 1919 we saw in England the coming of the low-horsepower general-utility family automobile that was light in essence but had already begun to lose its qualifications for that epithet. The vast majority of the light-car patrons might not be exacting as to speed, silence, smoothness, or other attributes that are regarded as a *sine qua non* in 1927, but they were very definite in such matters as accommodation and equipment, largely, I think, stimulated by the American industry in, as far as possible, avoiding all extras and making the car to be delivered to the customer as reasonably complete as possible. In other words, they wanted their small vehicles to have the same desirable features as were obtainable in the bigger class of automobile.

Post-War Light Car Weighs More

Emerging from the World War as an exiguous two-passenger vehicle that had at most a dickey seat, the dimensions of which clearly indicated how seldom it was to be used, the light car of 1919 and 1920 quickly became a phaeton with a commodious body and proceeded to add to its weight by an electric lighting and starting installation, speedometer, clock, all-weather side-curtain equipment, detachable wheels, sliding front-seats, spare gasoline tank, luggage carrier, rear windscreen, and all sorts of other paraphernalia, which previously had never been associated with the original light-car at all, or, for the matter of that, so far as England and Europe are concerned with any other type of automobile. It is not surprising therefore that this development involved a very considerable addition to weight and I think it calls for remark that the light-car engine designer was able to keep pace with the demand made upon his powerplant.

In spite of all this increase in size, for wheelbases had to be lengthened to accommodate larger bodies, and axle and gearbox dimensions increased, he managed with his engine of very little more than 67.1-cu. in. capacity to maintain his road performance almost unimpaired. The general tendency was, as might be expected, to lengthen the effective scale of engine revolutions by increasing compression-ratios, stiffening crankshafts and lightening all reciprocating parts. In this latter point, of course, very considerable aid was derived from the use of aluminum-alloy pistons, which quickly showed that the small-capacity engine could run with a very agreeable absence of perceptible vibration. The higher standard of smoothness, silence, and general absence of turmoil converted many thousands to the patronage of the light car who would otherwise have resisted its appeal, and this aspect is a very important, if not predominant, factor in the general excellence of these little cars.

Better Grade of Light Car Demanded

A very considerable market is found among the large-car owners who wish to possess a light car that, to use a simile, is used as a hack to save the hunter. These large-car owners have their own standard and, be it said, a high one, of vehicle luxury, more particularly in respect of noise and vibration, and they certainly would not put up with light cars unless the latter were reasonably answerable to those standards. I think that this fact in itself represents, if I may say so, a great testimonial to the successful efforts of car designers in Europe.

But despite this rapid development, the fact must not be lost sight of that the light car by no means had the market to itself. Competition was particularly keen in the early years after the World War. For the most part, what I may call "full-blown" cars were relatively expensive except those imported from America, and the fact that these latter offered full-size accommodation at very low first-cost acted as a powerful urge and accounted for the rapidity with which the British light-car came into line as a British family vehicle. At that time, even as now, the Ford was the cheapest vehicle upon the English market. Very soon after the World War, its commercial application began to take precedence over its touring-car phase. It was so commonly used for business purposes that it ceased to maintain its appeal to the

private motorist. In England it is not that we are necessarily snobbish, but we have a marked tendency to individualism, which exhibits itself in this form, that we dislike driving an exactly similar car to that of our neighbors, or going forth on a tour in a vehicle which is of identical type as that which has brought the grocery and vegetables to our houses.

In these circumstances, there is in England always a market for the light car that is a little better than the most popular type. I think, however, that some small reservation must be made in connection with this point as economic forces have helped to overcome the "like-the-others" sales resistance, and though the feeling is still as strong as ever it was, that every man wants something different to his neighbor, he has had to give way to some extent, as the only means by which he can obtain an automobile within the compass of his purse is to let the manufacturer make as many of them as circumstances permit.

Three Price and Engine-Size Classes

I mention this because the light car in its earlier stages established itself purely upon the price basis, yet, just as the scaffolding disappears when the house is complete, so today that price basis, except in a competitive sense, has almost vanished from the light-car field. We

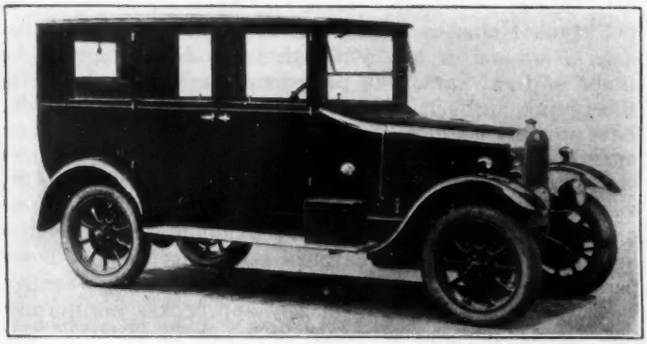


Fig. 3—The 11-Hp. Clyno Sedan

The Specifications for this Car Are Given in the Following Table

Tread, in.	48
Wheelbase, in.	105
Over-All Length, in.	154
Over-All Width, in.	61
Road Clearance, in.	9
Tires	27 x 4.4

have our cheap light-cars, our medium-price light-cars and the sports type or more highly specialized class of light car, the first two categories dovetailing into one another so closely that it is hard to say where one class ends and another begins. The sports type is more of a specialized market, and withal one of considerable potentialities which, in my opinion, has not been tackled with nearly sufficient vigor by the English industry. The light-car price-range therefore runs from the 7-hp. Austin at $703.25 to the 1½-litre (91.5-cu. in.) Aston-Martin which as a complete four-passenger phaeton is listed at $5,000.

Again, we have at least three well-defined classes of light car as judged by their engine dimensions alone. In this connection it is important and interesting to note that the competitions which have assisted so enormously, as I have indicated early in this paper, and which have rendered necessary the use of a capacity classification, have almost ceased to exist in England insofar as the automobile industry is concerned as a whole, as the conclusion has been reached that they do not any longer serve a useful purpose; one of the exceptions being the

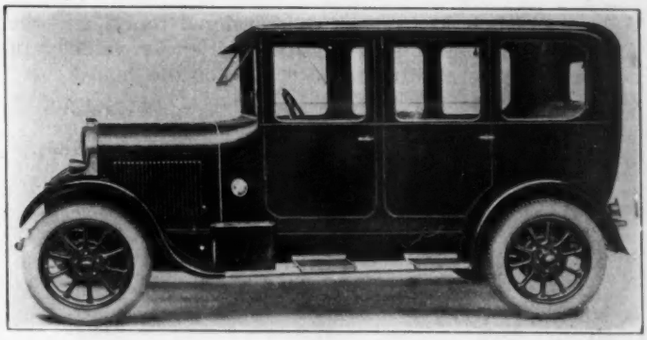


Fig. 4—The 10-26-Hp. Singer Sedan

The Specifications of This Car Are Similar to Those for the Phaeton. The Price Is Slightly Higher, $1,261

leading light-car event, namely, the Junior Car Club's 200-Mile Race, which has three engine-capacity classifications, 1500 cc. (91.5 cu. in.), 1100 cc. (67.1 cu. in.) and 750 cc. (45.7 cu. in.). This is not to say that the competition spirit and the Club activities are not as keen as they ever were, and the decision of the automobile industry not to support the many events was very unpopular, and the competitions are now confined to club members pure and simple; in other words, the amateur element is the only one encouraged.

Slight Relation Between Power and Weight

Although, as will be mentioned later, plenty of vehicles are turned out from English factories which deserve the name of "light car," though their engines have more than 91.5-cu. in. capacity, this may be regarded as the limit for the light car, using the phrase in its strictest sense. It will be observed that there is no real connection, although there is an incidental one, between the weight of the vehicle and the engine dimensions. I emphasize this point, however, to indicate the difficulty of otherwise defining the light car. Without doubt we do in England instinctively associate lightness with small engine capacity. For instance, we do not call the Ford a light car although its weight is considerably less than many vehicles that we do call light cars. We do not call the Essex a light car although there are light cars which may weigh a few hundred pounds more than the Essex. It is not to my purpose to apologize for this illogical state of affairs; it simply exists.

For the purpose of comparison, I give a schedule of the actual weights of some of the leading European light-cars of 91.5 cu. in or less, these weights representing the car as a standard phaeton, except in the case of the

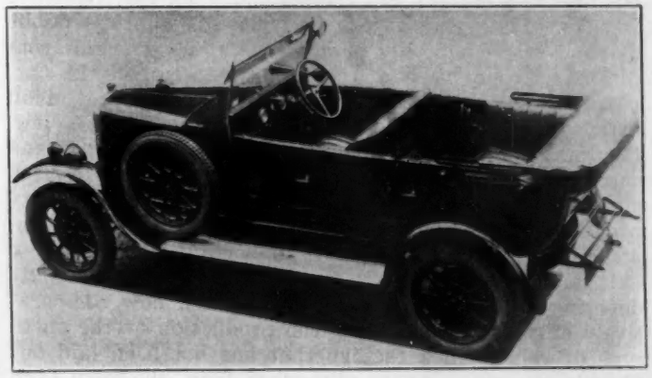


Fig. 5—The 11-Hp. Clyno Phaeton

This Car Sells for $836.60. The Specifications Are the Same as Those of the Sedan

Austin which is known as "an occasional four," and the Amilcar which is a sporting two-passenger vehicle, in normal running condition and ready for the road:

Car	Size, Hp.	Weight, Lb.
Austin	7	950
Amilcar	9	1,320
Renault	9–15	1,350
Trojan	10	1,460
A. C.	12–24	1,680
Clyno	11	1,800
Rover	9–20	1,800
Singer	10–26	1,800
Fiat	9	1,800
Wolseley	11–22	1,900
Morris	11.9	2,020
Fiat	10–15	2,240

As against these, the Essex car as turned out for use on ordinary British roads in the form of a standard five-passenger car, weighs 2300 lb., while the Ford phaeton weighs approximately 1800 lb. Except for the Austin which is of 45.7-cu. in. capacity, the Amilcar which is of 67.1-cu. in. capacity and the 9-hp. Fiat which is of 60.0-cu. in. capacity, all the automobiles in the above list are approximately 91.5 cu. in.

Comprise Two-Thirds of English Production

It will be fair to say that nearly two-thirds of the automobile production of England today is that of light cars, of which there are upward of 60 different makes, either built at home or imported from Europe, on the market, covering about 70 distinct chassis models apart altogether from variations in bodywork, that can reasonably come into the category of light cars. There is, I think, not the slightest ground for doubt that this proportion of output as compared with larger cars will continue to increase, not only on account of the growing efficiencies of performance of engines from 61 to 122 cu. in. but also that a not inconsiderable number of people are realizing that two light cars, say, one an open semi-sporting machine and the other a sedan, can be run at a lower cost than one large general-performance car; that so far as English use is concerned, the owner could put up a performance not greatly inferior to that of the large car on the type of road which he has to use in England, as it should be borne in mind that English road conditions are vastly different to those of any other country, in that they are twisting and winding, and large mileages are comparatively narrow, which makes high ultimate speeds unnecessary, the great demand obviously being for quick acceleration to 40 m.p.h.

To understand why the light car appealed to the manufacturer whose plant was yawning for work after the first few months had elapsed following the Armistice is easy. There was in the first place a manifest public demand that could only be accentuated as economic conditions became more and more pressing upon the taxpayer, additional to the enormously increased cost of all articles needful or otherwise. From his point of view, the light car was no experiment but was a proved and capable machine. It could be produced easily, more especially in factories not specifically laid down for quantity production, the question of weight of individual components being, of course, very important.

It is of some interest to those who are more especially devoting their time to factory problems, how comparatively easy it is to start up the production of the small type of vehicle in a factory that has not been laid out for the purpose. Apart altogether from the very high degree of elasticity that the average English automobile factory has, due in large measure to the smaller productions that rule, the problems of plant adaptation, floor space, prime-movers, and conditions generally are very much more simply solved than would at first appear to be the case and which, in fact, has been shown by experience.

Influence of American Ideas

It must be remembered that in my Country, and I speak generally, it is not possible, nor is it economical, for a plant ruthlessly to scrap outofdate machinery to make way for newer devices, and a very considerable adaptation of existing plant has to be undertaken. We are not able, for reasons into which I cannot enter in this paper, to think in anything like the figures for which your industry is famed. I should, however, like, if I may digress for a moment, to pay a tribute to the great amount of knowledge and accumulated experience that the English industry has acquired from its friends here in America, and to record the remarkable welcome and hospitality, and the imparting of anything and everything that is given by America's automobile engineers to those of other countries. It is always a matter of favorable comment among us at home as to the great freedom of interchange of knowledge and ideas that you have among yourselves as well as with your visitors, and I think I am safe in saying that we of the English industry are always anxious, so far as we can, to reciprocate this splendid cooperative spirit.

I think I must not leave out of count the great influence of racing of late years that has been strongly in favor of light cars, for, to reduce the speed of events, the racing authorities, under the Federation Nationale, have steadily lessened the limit of capacity. All last year and this year in Europe the racing events of importance were, and are, without exception confined to 91.5-cu. in. vehicles. The light-car builder has therefore had every opportunity of acquiring a large amount of knowledge and of making use of this most strenuous form of competition and at the same time employing for his racing work the type of car that closely approaches his normal product, or perhaps it would be truer to say that the racing types are becoming more closely approached by the normal product.

Ultra-Light-Car Ability Demonstrated

A word must be said about the ultra-light car, by which I mean its most famous representative the 7-hp. Austin, and, to a lesser extent, the 7-12-hp. Peugeot. It was the last-named firm that even before the World War placed upon the market a baby automobile, the practicability of which has been abundantly proved in the last few years. Judged by American standards, the output of the 7-hp. Austin is not very large, but it is certainly large according to British ideas of this type of car, and moreover the demand for this type is clearly increasing. Apart from the inherent excellence of the car, I think a large proportion of the increase is due to the fact that we have in Britain a wonderful system of roads from the point of view, primarily, of surface, and upon which we are spending in making and upkeep a sum of approximately $5,000,000 per week.

A vehicle with so short a wheelbase and so small an engine capacity could hardly be expected to establish itself in any country where first-class roads do not exist; but, as roads are being rapidly bettered in every country of the world, it is not surprising to find that this essentially English light-vehicle is being more and more demanded for export purposes. In fact, the same applies to light cars in general. Formerly, the principal objection as seen by the manufacturer and by the English

overseas markets was their unsuitability for export and this was a very serious objection, for it meant that the load factor of the factories was very seriously handicapped and they could only build on the basis of full production during the 6 car-selling months of the year. From August to February it was evident that home sales fell off. In the last year or two, however, a complete change has come over this aspect of affairs.

Exports to Colonies Are Growing

Our experience goes to show that the overseas market is now convinced of the capability of the English light-car to fulfill a very large proportion of the available market. Considerable work has been done to convince the potential buyer of the suitability of this type of vehicle and to show him why it should appeal to him, and without doubt the light car has begun definitely to establish itself as a favorite in these markets. Bearing in mind the difficulties that have had to be overcome, we can say that such firms as Austin, Morris, Clyno, Singer, Standard, and many others are doing a considerable volume of export business with Australia, India, New Zealand, the Federated Malay States, South Africa, and other countries and this business is on the increase.

I want now to give some idea of the scale of light cars on the British market. As I do not wish to cause any anxiety on your part that I may be proceeding to go through the 60 or so different makes, let me relieve your minds at once and say that I am only going to note a few of the more prominent.

Austin	$703.25
Citroen	800.25
Morris Cowley	836.60
Clyno	836.60
Renault	960.30
Swift	1,018.50
9-hp. Fiat	1,042.75
10–26 hp. Singer	1,067.00
Rover	1,164.00
10–15 hp. Fiat	1,430.00
A. C.	1,615.00
Talbot	1,915.00
Alvis	2,182.50
Riley	2,206.75
Bugatti	2,255.25

Of course some light cars go still higher in price but it will be readily understood that these more expensive types are of a distinctly specialized nature. It is necessary, however, to point out that the 12-hp. 91.5 to 92.1-cu. in. automobile costing between $2,000 and $2,500 is still, and probably will long remain, in very great demand in England and overseas, at any rate in the British Dominions. To use an hibernianism, it is a light car in all but weight. A vehicle like the Alvis, for instance, is normally turned out with a body that will give plenty of accommodation for four passengers and, like other light cars, it is fully equipped in every way and it has a performance which includes a road speed of well over 60 m.p.h. on the level at any time.

Details of Most Popular Light-Car

The most popular light-car built in England today is undoubtedly the Morris-Cowley, although I should remark that according to the competition rules in vogue in England the Morris-Cowley is not a light car at all inasmuch as its engine has a capacity of 91.8 cu. in. It is, however, definitely a light car according to British opinion, and the extra 0.35 cu. in. does not much matter in view of the fact that this manufacturer does not participate in races or other competitions. But the Morris does not by any means hold a monopoly and it is

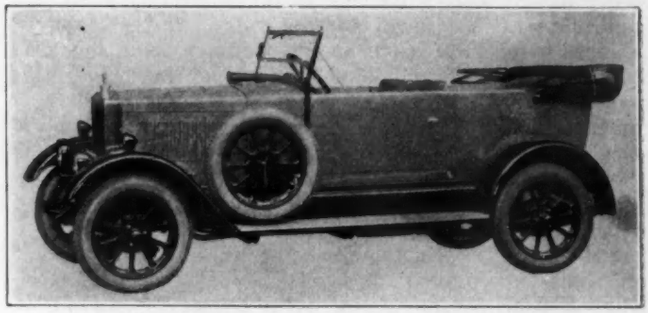


Fig. 6—The Morris-Cowley Four-Passenger Phaeton
This Car Is Rated at 11 Hp. and sells for $836.60

closely followed by the Clyno, the Citroen, and Austin with Singer and Standard as close followers.

I give, however, a brief specification of the 11.9-hp. Morris-Cowley, the chassis of which is shown in Fig. 1, as a typical case that will enable you to form some idea of its general design. Most of the other light cars answer to much the same specification though many of them exploit individual features of design. The engine is a four-cylinder of the monobloc type with detachable cylinder-head, having a bore of approximately 2.71 in. and stroke of 4.01 in. The crankshaft is carried on three bearings, the valves are arranged side-by-side, the camshaft being driven by spiral pinions in the ordinary way. The engine, clutch and gearbox form a unit, the clutch being of the single-plate type cork-faced and the gearbox containing three speeds forward and reverse, with central control. The transmission is effected by a propeller-shaft enclosed within a spherical-ended torque-tube; the final drive is by spiral-bevel. Half-elliptic springs are used fore-and-aft and are furnished with frictional-type shock-absorbers. The wheels are of the steel artillery-type and are demountable. Front-wheel brakes are fitted. Cooling is on the thermosiphon principle. Ignition is by magneto, and the electrical equipment comprises a single-unit dynamo and starter. It is needless to say that the material of which this car is made is of unexceptional quality having regard to the different functions it has to perform. The equipment includes almost

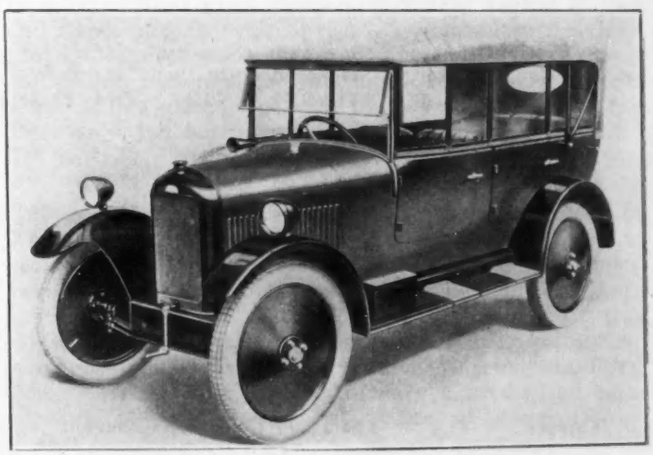


Fig. 7—The 8-Hp. Singer Junior Four-Passenger Phaeton
The Specifications of This Car Are

Tread, in.	42
Wheelbase, in.	90
Over-All Length, in.	139
Over-All Width, in.	52½
Road Clearance, in.	8¼
Tires	27 x 4

every device imaginable that could enhance comfort and convenience. A typical Morris-Cowley car is capable of a speed of over 50 m.p.h. under ordinary conditions and may be expected to do about 35 miles per gal. of gasoline under normal running conditions. Its accessibility is remarkably good, making for cheapness of repairs and overhauls, and the whole layout has been considered from the owner-driver's standpoint.

One of the reasons to which I have not yet alluded which led to the English light-car rapidly obtaining a vogue among motorists was some unexplainable but at the same time undeniable fascination on the part of the English user for an engine with a certain amount of "bite" or "devil" in it. No one could review the designs of representative British cars of all types and sizes without realizing that upon our side of the Atlantic we have no particular objection to changing gear, though I am not going to say for a moment that if gear-changing could be eliminated it would not be hailed by the ordinary public, certainly in England and I imagine everywhere else, as the greatest advance in automobile design since its creation. But I think it is true to say that we have not in England the same rooted objection which I believe is the case in America.

Why Three-Speed Gearbox Is Retained

I may remark that four-speed gearboxes are definitely becoming more popular than the three-speed type, and only economic considerations prevent their standardization universally. On the other hand the light car must obviously appeal to the novice motorist, and it is this class that will have the greatest objection to gear-changing. All the lower-price English light-cars have three-speed gearboxes, and such objection as rules to gear-changing has, of course, had to be tackled more especially in this category.

In spite of their small engine-size and relatively high weight, cars such as the Morris-Cowley sedan, that is illustrated in Fig. 2, the Clyno (Fig. 3), and the Singer sedan that is shown in Fig 4, will, when intelligently driven, do 90 per cent of their running on high gear. Back-axle ratios therefore have been reduced considerably, ranging from 5.9 to 1.0 up to 4.7 to 1.0 but, with the horsepower scale extended to cover a much higher rate of revolution, performance still keeps up and every effort is made to keep the bottom end of the curve as flat as possible. Specimen performances are given in Table 1. One observes, with a very large number of drivers of light cars, such as those illustrated in Figs. 5, 6, and 7, even when thick London traffic has to be negotiated, that they will only use second and high gear, the former for starting from rest. I am not going to condone this pernicious practice, but such is the case.

Commercial and Tractor Applications

A development arising from all this small-engine type of vehicle is showing remarkable potentialities. I refer to the commercial applications of these vehicles among a large variety of users. A large number of light-car chassis are being turned out fitted with delivery-van bodies to carry from 600 to 1800 lb. A high percentage of the commercial traveler's work is done in these little vehicles, obviously with great saving of staff, and very much better attention given to his customers. There is, I think, little doubt that this type of automobile is providing a ground for keen competition. That private users may not be prejudiced by this state of affairs, that is to say, by the use of well-known makes for trading purposes, to which I referred earlier, some companies are using a different type of radiator on the tradesmen's chassis to distinguish it from the private-car type.

Another and, I think, somewhat unexpected and certainly interesting development of the light car is in the direction of the tractor for agricultural and military purposes. An enormous amount of work has been done in this connection, the two greatest protagonists, or perhaps I should say, antagonists, being Morris and Citroen. They have produced "go-anywhere" vehicles, using the flexible-track method of propulsion and these vehicles, no longer experimental, have been put through

TABLE 1—SPECIMEN PERFORMANCES OF LIGHT CARS

Make of Car	Horse-power	Bore and Stroke, In.	Capacity, Cu. In.	Body	Maximum Speeds on High and Gears, M.P.H.	Acceleration from 10 to 30 Miles per Hour, Sec.	Stopping Distance from 40 M.P.H., Ft.[2]	Gear Ratios	Total Weight,[3] Lb.
A. B. C.[4]	12–40	3.71 x 3.60	79.3	Two - Passenger	67, 47, 30, 20	9, 6, 6	102	13.77, 9.45, 6.5, 4.5	1,716
Standard	11	2.60 x 3.45	79.7	Phaeton	48, 32, 14	17.6, 12	171	20, 8.7, 4.6	1,860
Hampton	12	2.70 x 3.90	91.25	Phaeton	52, 42, 27, 16	17, 10	106	16.68, 10.5, 6.86, 4.5	1,960
Fiat	10–15	2.58 x 4.30	88.45	Phaeton	50, 33, 25, 14	15.2, 9.2	183	22.63, 12.83, 8.94, 5.11	2,520
Talbot	10–23	2.35 x 3.70	65.6	Phaeton	53, 40, 20	18.4, 9.4	139	19.42, 9.35, 5.11	1,848
Senechal	8	2.39 x 3.90	67.1	Phaeton	50.9, 37, 22	15, 9.4	63	13, 8, 4	1,628
Fiat	7	2.20 x 3.73	60.39	Saloon	48, 30, 16	14.8, 13.8	133	20.075, 12.083, 6.111	2,156
Citroen	11.4	2.68 x 3.90	88.63	Phaeton	48, 30, 16	17, 14	151	15.6, 5.8, 4.9	2,184
Clyno	11	2.60 x 3.90	83.5	Phaeton	50, 32, 17	17.5, 14.5	107	16.5, 8.9, 4.8	2,072
Morris	11.9	2.70 x 4.00	91.8	Phaeton	50, 35, 18	17, 12	103	15.2, 8.17, 4.75	2,020

[2] All cars are fitted with only two-wheel brakes.
[3] Allowing for two passengers of total weight of 280 lb.
[4] The A.B.C. Super-Sport is a two-cylinder air-cooled engine.

the most severe tests to which it is possible to submit any vehicle, namely, War-Office stunts. Not only that, but the Citroen has to its credit its wonderful trips across the Sahara from Taggourt to Timbuctoo and back, and right across the African Continent from Morocco to the Tanganyka country, and I think as a result of the success obtained by these two vehicles there will be other manufacturers who will follow, and a large market will be found for these handy and cheap vehicles in development work in uncharted country.

Having considered to a limited extent the development of the light car as we know it, down to date, it would now, I think, be opportune to consider what future probabilities there are, and here I am in danger of indulging in the very risky occupation of prophecy. It is said that "a prophet is not without honor save in his own country." In spite of my being out of my own Country, I do not aspire to this honor, but I think it is interesting to record two very unorthodox and certainly intriguing types of vehicle, one of which is a sound commercial proposition and is doing very well, the other at present experimental but being put on the market. They both embody principles in design which are distinctly original.

Novel Two-Cycle General-Utility Car

The Trojan and the Constantinesco are the two makes to which I allude. The former is equipped with a two-cylinder two-stroke engine, $2\frac{1}{2}$ x $4\frac{5}{8}$ in., and is rated at 10 hp., giving a capacity of 90.7 cu. in., combined with a two-speed-and-reverse epicyclic gear with a final-drive by chain. In spite of its radical departure from conventional design, the Trojan has a very strong market in Great Britain as a foolproof, extremely economical and sound general-utility car that is suitable for private as well as for light commercial work. It has a very considerable use among the farming fraternity and for rough work of all descriptions. Owing to the peculiar design of the engine the horsepower curve rises rapidly from the zero-point and remains flat over most of the scale of revolutions. It therefore has no great maximum speed but it will travel along over ordinary undulating sort of country very nearly as fast uphill as down and on the level, and its control therefore so far as the engine and gears are concerned is practically nil. The cheapest model is fitted with solid tires with a special system of springing to accompany them, although another model is fitted with pneumatic tires. It is certainly not an automobile for the connoisseur but it was never intended as such. It is cheap in first cost and extraordinarily cheap to run. The standard model costs $625.

Constantinesco Gearless 30.5-Cu. In. Car

In the Constantinesco car an extremely original transmission scheme is adopted which eliminates all clutches and gears, using in their place the Constantinesco torque-convertor that doubtless is well known to all my hearers as a form of infinitely variable gear working upon the inertia or pendulum principle. The engine is distinguished by the fact that it is the lowest-powered prime-mover of any four-wheel automobile that exists, the engine being a two-cylinder two-stroke type with a total capacity of less than 30.5 cu. in. The automobile has a top speed of less than 40 m.p.h., but it has shown under test that it can average 28 m.p.h. over ordinary roads with two passengers. The designer's reason for the two-stroke principle is that the pistons of the engine may balance the moving parts of the torque-convertor mechanism, which result would not be directly obtainable with a four-cylinder engine of the ordinary

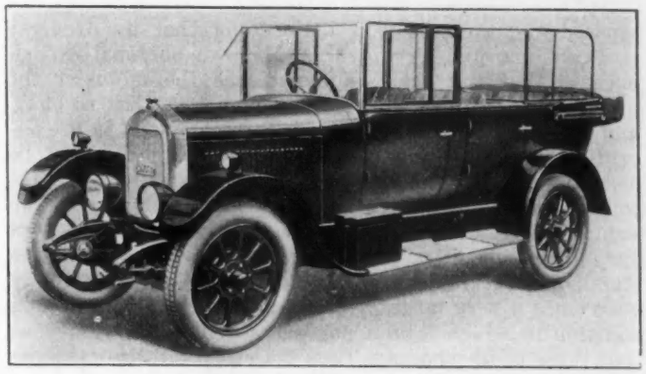


Fig. 8—The 10-26-Hp. Singer Phaeton

The Specifications of This Car, Which Sells for $1,067, Are Given in the Following Table

Tread, in.	48
Wheelbase, in.	103½
Over-All Length, in.	164
Over-All Width, in.	65
Road Clearance, in.	8¼
Tires, in.	28 x 4.95

type. As to whether an automobile driven through a torque-convertor has any future I will leave engineering minds better qualified than mine to decide, but ranging over the whole history of automobilism since its inception we have all doubted so many things that have become practical propositions that one gets scared of offering a too definite opinion on any new invention in its early stages of development.

I have already alluded to the manner in which immediately after the World War the light car rapidly grew much heavier owing to the use of more commodious bodywork and to the addition of more elaborate detailed equipment. At the present time, it would not be far from the truth to say that the four-passenger sedan with either two or four doors is rapidly becoming the standard type of body for light-car chassis. On all hands, manufacturers who exhibited at the recent Olympia Show report an increased demand for the permanently closed car. Needless to say, the construction of these sedan bodies has required and is receiving very much attention. It is this aspect up to the present, I think, where the English industry has had the greatest difficulties. Body production has always been, and I suppose always will be, a problem of great complexity having regard to line and finish and therefore price. The small productions that are common make it extraordinarily difficult to keep cost within reasonable bounds, and looked at purely from a low selling-price standpoint the obvious answer is the steel body, but here again it implies big production.

Steel and Flexible Closed Bodies Coming

Two of the manufacturers, one in England and one in France, namely, Morris and Citroen, have started to tackle the steel-body problem in conjunction with members of the American industry, and I believe big plans are maturing, or have matured, in connection with this method of construction. It would seem that in due time a marked indication of this will be reflected in selling price if it is found possible to have a production commensurate with the very big first cost of preparation.

Other manufacturers almost without exception are still continuing bodies with wooden framing and metal panels, and the Weymann flexible system is becoming more and more in demand. Its growth to popularity in England has been slow, owing possibly to the fact that it is in a measure unconventional, and therefore has been looked on with suspicion, but this suspicion is fast being dis-

sipated and there is very little doubt that its progress will continue uninterruptedly. My own personal experience is that the older in experience the motorist the quicker he is to see what a Weymann body has to offer, and this type of body has much to recommend it in connection with the light car, as chassis frames cannot be as heavy as one would like to make them, owing to weight considerations, and with the growing popularity of the sedan where considerations due to chassis whip and springing difficulties are of great importance from the standpoint of creating rattles, the flexible type of body overcomes a very large proportion of these difficulties, in addition to which it is a non-drum body, and I am sure that those of us who have been bothered with this trouble would be very glad to be relieved of it.

In view of the fact that the typical 11.9 hp. English light-car rarely has a wheelbase of more than 105 to 108 in., it is really remarkable how comfortable these small closed cars can be made.

Annual Running and Upkeep Cost $750

This paper could not, of course, pretend to be a complete disquisition upon the light car though it is hoped that the more important points have been touched. It would, however, seem essential that some direct reference should be made to running costs. Taking a typical phaeton like that shown in Fig. 8 and costing initially $1,000, the running costs which I submit to you work out approximately as follows. It is to be pointed out that they will often be distinctly less than the figures given, but I have set these out on a deliberately conservative basis:

Interest	$50.00
Depreciation	375.00
Insurance	60.00
Tax	60.00
Repairs	30.00
Gasoline (30 miles per gal.)	112.50
Oil	12.50
Tires	50.00
Total	$750.00

You will note that I have only allowed for 30 miles per gal. of gasoline. This item and also $50 for tires I consider on the high side, as also $30 for repairs, but they will serve. They are based on a yearly mileage of 10,000, and it will be seen that this works out at 7½ cents per mile. First-class railroad travel in Great Britain is 6 cents per mile, so that if two passengers are habitually carried in the car, the latter represents a definite saving and, of course, the cost per passenger-mile when considered from the point of view of a fully loaded automobile is not comparable. A somewhat high figure for depreciation has been taken, at any rate it would be looked on as high in England, but in view of the steady downward trend of prices and the used-car problem generally, I think this figure is about right. In the second year a light car of reputable make should not depreciate by more than a further 20 per cent, so that in the second year's running the cost per mile should be if anything rather less. I am assuming reasonable intelligence on the part of the user and that he takes proper care of his automobile.

Capability and Life Fully Demonstrated

In England the owner does not expect to have his automobile wear out too quickly: still the question is always asked and is ever present in the mind of the user and in that of the prospect, "Will it last?" A very large business is done in complete overhauls and repainting, which I believe is not so customary under American conditions. The user therefore expects to get a fairly long life out of his car. He knows that if he gets rid of it he will lose money every time. Under normal circumstances therefore he will expect 4 or 5 years' use, and one sees on the English road thousands of light cars already as old as this, and older, that are doing perfectly satisfactory work. Their market value is not high, of course. As to whether or not it pays the user in the long run continually to overhaul and paint his car is a question that cannot easily be settled. What is certain is that it does not make for as brisk a manufacturing trade as one could wish.

The question now arises, Does the light car fulfill its purpose and will it remain a stable type? I think I can answer the first question in an emphatic affirmative. The capability of this type of automobile is proved beyond any question, and that it does fulfill its purpose I think the best answer is the balance sheets of the chief producers of light cars. It is a fact that among the most successful companies in the English automobile industry are the light-car builders. Morris, for instance, succeeded in netting over $5,000,000 per year for 1923, 1924 and 1925 respectively, which are very high figures indeed in proportion to his capital employed.

There are also the very severe journeys that these light cars have made successfully, which their designers can hardly have intended. I will not take your time by enumerating any of these in detail but they are of definite interest from a design standpoint, and include runs from London to Constantinople, London to Calcutta, right across Australia and South Africa, from one end of New Zealand to the other, and many other journeys of indescribable difficulties involving abuse of every sort to the car.

Semi-Light Six-Cylinder Type Expected

In regard to the second part of the question, Is the light car, so to speak, stabilized? This answer is more difficult to give. It is, as I have already indicated, the foundation of a large industry in itself but at the same time I think that design is in a state of flux, but as there is no hard and fast rule as to what constitutes a light car, it is not easy to be very specific. In the growingly popular class of vehicles, namely, engines between 91.5 and 122.0 cu. in., we certainly see the light-car principles exercising a beneficent influence. Beyond 91.5 cu. in. these vehicles cannot be strictly called "light cars" and yet they are far more nearly related to the light car than they are to the large car. It is easy to see how their existence has been brought about; the British public, having learned to appreciate light-car economy and general satisfaction, has begun to demand a car that is just a little more powerful and just a little more roomy, and I think that its future development will depend, so far as England is concerned, to a very large extent on the financial situation. So long as England carries the enormous burden of taxation, by which I mean not only the personal taxation but the general effect on industry of high taxation, so long will design keep fairly stable as price is to a very large extent the governing factor.

There is, however, a marked sign of the desire of various manufacturers to develop along the line of the six-cylinder engine, and I feel sure that within the next year or so there will be a large number of makes, including what I may describe as six-cylinder semi-light cars, of a distinctly luxurious type. Already it may be said that some of the automobiles which have been

produced are competing for patronage directly with much larger and more expensive types but I do not think that this tendency will in the least affect the popularity of the light car proper, the demand for which is steadily rising. Also, owing to the employment of more economical means of production, its price shows a steady tendency to decline, and consequently new sources of demand are constantly being tapped. It is not too much to say that, in spite of the very high cost of living in Great Britain, a man with an income of $2,500 a year, and there are many such, can afford to run some of the more modest types of light car. At any rate, I am entitled to say that, as an industry, a spirit of very high optimism rules in connection with this matter, and we look forward both in our home market as well as overseas to increased sales and therefore prosperity.

HARDNESS TESTING

HARDNESS, machining properties and wearing qualities are three totally different characteristics of a metal, and in selecting a method of hardness testing the other properties required in the finished component must be kept in mind. Among the numerous methods that have been adopted for testing hardness, perhaps the most usual shop-method consists merely in trying the effect of a small dead-smooth file, and after constant practice the degree of accuracy that can be obtained by this method alone is astonishing. It cannot, of course, be relied upon to give good comparative results with all metals, but it is useful for testing the suitability of chisels, punches, shear blades, and kindred tools. A similar test consists in trying the effect of the metal on ordinary glass. If it is possible to scratch the glass, the metal is in a "glass-hard condition," distinctly hard and probably very brittle.

The Brinell Method

Foremost among the more scientific methods of hardness testing, the Brinell method may be mentioned as being the one most universally adopted, in spite of its many disadvantages. As a means of determining the approximate tensile-strength of steel and thus saving the expense of machining a test piece, it is excellent. The hardness in this case is calculated from the area of the indentation produced by applying an extremely hard steel ball with a given load to the polished surface of the metal.

Usually the load is 3000 kg., (6613.87 lb.) when using a ball 10 mm. (0.3937 in.) in diameter on steel while loads of 500 to 1000 kg. (1102.31 to 2204.62 lb.) are used for non-ferrous metals and alloys. In the latest machines hardened conical penetrators and diamond points of pyramid form are employed in place of the steel ball, but the method remains substantially the same.

With regard to the limitations of the Brinell test, it is first of all obvious that components of light section cannot be adequately tested because the ball may cause distortion right through the metal. Extremely hard metals also cannot be satisfactorily tested since they are apt to distort the ball. In this connection the importance of frequently renewing the ball may be emphasized, since, should it become flattened, it would give very erroneous results.

A further objection to the Brinell test is that the impression produced on hard steel is so small that it is frequently difficult to measure it with sufficient accuracy. To overcome this a ball which has previously been etched for about 1 min. in a 2-per cent nitric acid in alcohol solution, may conveniently be substituted for the ordinary polished ball. This gives an impression with more clearly defined edges, so that the exact measurement is simplified.

Still another objection to the Brinell test is that metals having a coarsely crystalline structure will give very different results according to the position of the indentation. Moreover, when the adjacent crystals are of varying hardness, accurate measurement is impossible. For similar reasons unreliable results will be obtained from cast iron containing a large percentage of free soft graphite.

Difficulties are also likely to arise in testing case-hardened steel by the Brinell method, particularly if the depth of the case is not great. The case itself may consist of high-carbon steel having a Brinell hardness of over 600, while the low-carbon core may have a hardness number between 120 and 180. In such circumstances, if the case is at all thin, the deformation is likely to extend into the soft core, giving rise to entirely erroneous results. To detect defects in homogeneity of metals by the Brinell method is sometimes possible. It will also indicate heat-treatment when varying results are obtained from tests taken at a number of different points on a heat-treated article.

The Scleroscope Method

The scleroscope test is also extremely easy to apply, while the small indentation that it produces will not mar even the lightest and most delicate component. The scleroscope hardness of hard steel is approximately 100. This test is useful for ascertaining the hardness of thin sections of metal and can also be employed for case-hardened steel. Obviously, however, the results obtained are influenced by different factors from those governing the Brinell test because, to quote an exaggerated case, substances such as rubber and celluloid give readings equal to those obtained with hardened steel. Were it not that the hammer produced a minute permanent indentation in the metal, this test would give a true indication of the elasticity of the specimen.

The Saniter and Other Tests

For determining the wearing properties of a metal, the Saniter test is frequently employed. For this purpose the most usual method consists in using a test piece 5 in. long by ½-in. diameter, which is fixed in a chuck revolving at 4000 r.p.m. At the free end of the test piece the inner race of a ball-bearing is rotated by friction, the ball-bearing being loaded to produce a pressure of 205 lb. at the point of contact. Under these conditions the wear or hardness number is the amount measured in 10,000ths of an inch, which is removed from the test piece after it has made 200,000 revolutions. This test was originally devised to estimate the wearing properties of various rail-steels, and the object was to reproduce so far as possible the actual stresses met with in practice. The test will give results that are very different from those obtained by the Brinell or scleroscope methods, the most striking instance of this being the behavior of the well-known 12 to 14-per cent manganese steel. This gives a Brinell hardness number as low as 200, while the tensile-strength is approximately 55 tons per sq. in. In spite of the low Brinell number, however, the steel will wear infinitely better than any other steel, even one possessing a Brinell number as high as 650.

Other hardness tests occasionally employed are the Pellin, Turner and Du Nord, but the above-mentioned tests, including the numerous modifications of the Brinell method, are those most commonly adopted in practice. Provided the results obtained by them are intelligently considered, they furnish information that is extremely valuable in all branches of engineering.—*Automobile Engineer.*

Detonation Characteristics of Petroleum Motor-Fuels

By Samuel P. Marley[1], Donald R. Stevens[2] and W. A. Gruse[3]

Annual Meeting Paper *Illustrated with* Drawing and Charts

ABSTRACT

An examination for detonating qualities of 18 petroleum gasolines was made by the authors, the methods used being those of direct engine-tests and of chemical analysis. A single-cylinder lighting-plant engine, suitably modified, and a direct-reading detonation-indicator were utilized and they are described. The method of Morrell and Egloff was followed in the chemical analysis. This consists in determining the proportions of paraffins, naphthenes, unsaturated and aromatic hydrocarbons and calculating the aromatic equivalence of the hydrocarbons so found by the use of data compiled by Ricardo on the relative knock-reducing tendency of unsaturated hydrocarbons, naphthenes and aromatic hydrocarbons. These data indicate an equivalence expressed by the ratio 5 to 4 to 1.

Experiments were made in which a constant proportion of one hydrocarbon of each class was added to a gasoline, and the detonating tendency of the resulting mixture was determined by engine test. Use of two gasolines as base fuels and a system of inter-comparisons gave results indicating, for the particular experimental conditions and for the hydrocarbons used an equivalence indicated by the ratio 2 to 2 to 1. The examination by engine test involved comparing each gasoline with mixtures of a standard gasoline and benzene or kerosene. The mixture equivalent to each gasoline gave the so-called benzol equivalent. The equivalent was determined for each gasoline against two standard fuels, one a straight-run Mid-Continent gasoline and the other a good average motor-gasoline. It is pointed out that the degree of correlation between results by engine test and results by chemical analysis will vary with the quality of the standard fuel employed. In general, the benzol equivalents calculated from chemical analysis did not agree satisfactorily with those found by engine test. In the absence of published data on the influence of volatility of gasoline fractions on detonating tendency, a straight-run Mid-Continent gasoline was fractionated into 18-deg. fahr. fractions, and succeeding fractions were then added to the original gasoline in fixed proportions. The distillation data and detonating tendencies of the mixtures are given. The work confirms the general belief that detonating tendency increases with rise in boiling-point. The indications of the work are that petroleum gasolines of satisfactory antiknock value are available, and that the detonating tendency of gasolines is best determined by direct engine-test.

THE recent activity of the petroleum industry in producing non-detonating motor-fuels has centered much attention on the gasolines made by cracking processes. Cracked gasolines are believed to differ from straight-run gasolines in having a higher content of olefins, and possibly of naphthenes and aromatics. The relatively high non-knocking value of these types of hydrocarbons has been generally recognized. Various methods of measuring detonating tendency have been proposed and discussed, including the variation of compression-ratio or of spark-advance with fixed compression to the point of incipient detonation, the use of a variety of indicators and the estimation of the amount of detonation by listening. It has also been proposed to evaluate gasolines for antiknock qualities by chemical analysis. In the absence of published data on the quality of various cracked and other gasolines on the market, it has seemed desirable to us to present the results of a study of some of these materials. A single-cylinder engine, modified for the purpose, and a direct-reading detonation-indicator were employed in the investigation. This equipment has proved its value during several years of use.

The Test Engine

The test apparatus employed in this work was a 1250-watt, magneto-ignition, Delco lighting-plant, with the engine modified for our purpose. The stock cylinder and piston were replaced by a cylinder and piston from an 850-watt engine of the same make, and high compression was obtained by the use of a special water-cooled head, having a combustion-chamber similar in shape to the original. Spark-timing was rendered adjustable by making the camshaft housing rotatable. The mixing-valve was replaced by a specially designed carbureter having three cups maintaining the same fuel level, all feeding through the same metering-orifice. The temperature of the air supplied to the carbureter was regulated by an exhaust stove. A load-controlling device and power-recording instruments were used.

The Detonation Indicator

The indicator used is a modification of the bouncing-pin type and is shown in Fig. 1. Instead of leaving the pin free, as in the Midgley gas-generating indicator, the pin is tapped into the indicator piston and held rigidly at the top by lock-nuts, the tension on the main spring being adjustable. The shock of the detonation is transmitted to an anvil secured to the short arm of an indicating-lever, the long arm of which travels over a scale. Movement of this lever is damped by a very light spring. The indicator is adjusted so that, when the engine is not detonating, the lever shows but slight movement. The degree of detonation in the engine is controlled by adjusting the carbureter, the spark-timing and the load on the generator. A more intense detonation is indicated by a higher scale-reading. A compression-ratio of 5.5 to 1 was adopted for these tests.

In making a test, the standard fuel is made to detonate so that the indicator lever gives a reading at the middle of the scale, thus affording readings for both better and worse antiknock values. Changing to a fuel of better

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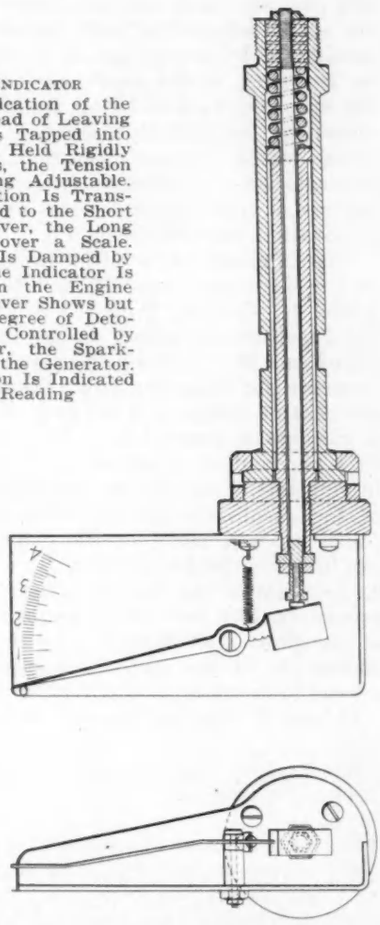

FIG. 1—DETONATION INDICATOR

The Indicator Is a Modification of the Bouncing-Pin Type. Instead of Leaving the Pin Free, the Pin Is Tapped into the Indicator Piston and Held Rigidly at the Top by Lock-Nuts, the Tension on the Main Spring Being Adjustable. The Shock of the Detonation Is Transmitted to an Anvil Secured to the Short Arm of an Indicating Lever, the Long Arm of Which Travels over a Scale. Movement of This Lever Is Damped by a Very Light Spring. The Indicator Is Adjusted So That, When the Engine Is Not Detonating, the Lever Shows but Slight Movement. The Degree of Detonation in the Engine Is Controlled by Adjusting the Carbureter, the Spark-Timing and the Load on the Generator. A More Intense Detonation Is Indicated by a Higher Scale-Reading

antiknock value will then give a lower scale-reading. As an example of the method of recording used, if the standard fuel gives an indicator reading of 20 on the scale and the test fuel gives a reading of 10, this result is recorded as 20-10. The gasolines used in this work are described in Table 1.

[5] See *Industrial and Engineering Chemistry*, April, 1926, p. 354.

[6] See *Proceedings of the Institution of Automobile Engineers*, vol. 18, part 1, p. 51.

[7] See *Proceedings of the Institution of Automobile Engineers*, vol. 18, part 1, p. 83.

METHODS SO FAR PROPOSED

It is generally agreed that the various methods so far proposed for the chemical analysis of the complex hydrocarbon-mixtures present in commercial gasoline are not rigidly exact. Recently, Egloff and Morrell[5] have combined what are possibly the most convenient of these methods into a procedure for the determination of four classes of constituents; namely, paraffins, naphthenes, aromatics, and unsaturated hydrocarbons. Using data obtained by Ricardo[6], they calculated the equivalence of naphthenes and unsaturated hydrocarbons in terms of aromatics, thus arriving at a calculated aromatic equivalent for each fuel analyzed. Use of further data of Ricardo[7] permitted reading from the calculated aromatic equivalent a "permissible" compression-ratio at which the fuel should operate satisfactorily. The variations in this permissible compression-ratio thus served to rate the gasolines as to their detonating tendency. Such a procedure involves two fundamental assumptions; first, that all the hydrocarbons in one class, say paraffins, have the same value; second, that results with all engines will correspond to those obtained with the engines used by Ricardo.

We have felt that such a procedure would be of great value if its validity could be established. Therefore, we have submitted the 18 gasolines listed in Table 1 to analysis by this method and also to engine tests.

ANALYSIS OF GASOLINES

The Egloff and Morrell method of analysis was followed for the determination of the proportions of the four types of hydrocarbons present. The method consists briefly in determining the unsaturated-hydrocarbon content by measuring the absorption and the polymerization losses to 80-per cent sulphuric acid, the aromatics by nitration and determining the volume of nitro bodies formed, the naphthenes by the aniline-point method and the paraffins by difference. Check determinations were made of each analysis, the averages appearing in the table. Table 2 gives the analyses of the 18 gasolines studied.

As presented in Table 2, the entries have been grouped

TABLE 1—DESCRIPTION OF GASOLINES

Gasoline	Specific Gravity[4]	Deg. Fahr. Initial Boiling-Point	Deg. Fahr. Dry-Point	Proportion Distilled Off, at Deg. Fahr. 221	284	392	Recovery, Per Cent
1—Straight-Run Mid-Continent *A*	58.8	118	426	28.5	55.0	91.0	96.0
2—Straight-Run Mid-Continent *B*	58.8	132	426	24.5	51.0	91.5	97.0
3—Special *A*	55.8	131	425	21.5	52.0	93.0	97.0
4—Motor *A*	58.7	112	428	28.0	53.5	91.0	96.0
5—Special *B*	60.9	106	408	32.0	65.0	94.0	95.0
6—Special *C*	56.7	108	430	30.0	58.5	90.0	94.0
7—California	52.7	132	430	22.0	50.0	92.0	97.0
8—Straight-Run Pennsylvania	63.1	128	440	32.0	67.0	91.0	95.0
9—Motor *C*	62.9	110	475	27.0	51.0	86.0	93.5
10—Untreated from Pressure-Still Distillate *A*	60.3	122	416	30.5	65.5	94.0	96.5
11—Treated from Pressure-Still Distillate *B*	58.8	128	410	30.5	61.0	95.0	97.0
12—Cracked Smackover	58.1	116	436	31.0	55.0	91.0	96.0
13—Motor *B*	59.2	110	436	26.0	53.0	88.0	94.0
14—Cracked Mid-Continent	56.6	107	436	26.0	45.0	84.5	95.5
15—Untreated from Pressure-Still Distillate *C*	55.2	117	427	23.0	41.0	84.0	96.0
16—Untreated from Pressure-Still Distillate *D*	56.6	115	434	24.5	48.0	89.0	95.5
17—Cracked Pennsylvania	57.1	138	458	17.0	40.5	85.0	97.0
18—Vapor-Phase Cracked	46.9	166	410	17.5	58.0	94.0	97.0

[4] American Petroleum Institute degrees.

TABLE 2—ANALYSIS OF GASOLINES

Gasoline	Percentage: Unsaturated Hydrocarbons	Aromatic	Naphthenes	Paraffins
1–Straight-Run Mid-Continent, *A*	2.8	3.9	19.7	73.6
2–Straight-Run Mid-Continent, *B*	2.6	5.0	19.5	72.9
3–Special *A*	1.7	9.4	18.9	70.0
4–Motor *A*	5.2	10.0	16.9	67.9
5–Special *B*	7.5	11.4	18.5	62.6
6–Special *C*	3.5	10.4	28.1	58.0
7–California	2.2	7.3	31.7	58.8
8–Straight-Run Pennsylvania	2.5	trace	14.9	82.6
9–Motor *C*	3.9	3.2	10.7	82.2
10–Untreated from Pressure-Still Distillate *A*	17.8	20.6	12.1	49.5
11–Treated from Pressure-Still Distillate *B*	17.4	20.2	12.8	49.6
12–Cracked Smackover	16.8	23.1	12.1	48.0
13–Motor *B*	13.0	18.0	12.6	56.4
14–Cracked Mid-Continent	15.0	18.5	12.6	53.9
15–Untreated from Pressure-Still Distillate *C*	19.6	22.5	11.1	46.8
16–Untreated from Pressure-Still Distillate *D*	20.2	23.0	8.6	48.2
17–Cracked Pennsylvania	11.7	16.7	6.7	64.9
18–Vapor-Phase Cracked	29.5	44.7	12.4	13.4

to show certain similarities in composition, and the several groups so formed are evident. Particularly striking is the group made up of gasolines Nos. 1, 2 and 3, in which No. 3 differs widely in origin from Nos. 1 and 2. The group formed by Nos. 10 to 16, gasolines made by cracking Mid-Continent products, is also noticeable. The members of this group are similar, not only in composition, but, as will be seen later, in engine performance also.

To test the accuracy of the method of analysis, synthetic mixtures of pure hydrocarbons, one of each of the classes considered, were made up and analyzed. The hydrocarbons were normal heptane, hexylene, methyl cyclohexane, and chemically pure toluene. Mixtures were made to duplicate gasolines Nos. 1, 14, 17, and 18. Only Nos. 14 and 17 were analyzed, but all four were used in engine tests. The composition and the results of the analysis are given in Table 3.

Method of Engine Testing

In making a series of tests, the engine is run until uniform temperature has been attained. Speed, load and other conditions are then adjusted so that the standard fuel will give the desired reading on the indicator. It may be said that, with a standard fuel, the same degree of detonation can be obtained from day to day with only minor adjustments of the engine and the indicator. These adjustments are required because of uncontrollable variations in condition of spark-plug points, breaker-points, valve and piston seal, and the like. With a standard degree of detonation obtained on the standard fuel, the supply is changed to the fuel under test by turning a three-way cock.

After the engine has adjusted itself to operation on the new fuel, readings are made on the indicator. Changes back and forth from the test fuel to the standard fuel are made several times. Usually, the readings for each fuel are constant, but any slight variations are minimized by averaging all readings. Enough benzene or kerosene, as the case may be, is then blended with the standard fuel to bring the degree of detonation, as shown on the indicator, down or up to that of the fuel being tested. In securing the results here presented, separate sets of observations were made by two observers at times several weeks apart. Very satisfactory duplication was obtained.

The 18 gasolines listed in Tables 1 to 3 were examined in the foregoing manner, and the results are given in Table 4. Column 1 gives the aromatic equivalents of the gasolines examined, as calculated by the method of Egloff and Morrell from the results of the analyses. This rests on the deduction from the work of Ricardo that 5 per cent of olefins or 4 per cent of naphthenes present in a gasoline is equivalent in the reduction of detonation to 1 per cent of aromatics. From the figures obtained by analysis, a calculation can thus be made of the value of the gasoline in terms of its aromatic content. The following will serve as an example. Gasoline No. 2, straight-run Mid-Continent *B*, contained, by analysis, 2.6 per cent of unsaturated hydrocarbons, 5.0 per cent of aromatics, 19.5 per cent of naphthenes, and 72.9 per cent of paraffins. Dividing 19.5 by 4.0, and 2.6 by 5.0, and adding the 5.0 per cent of aromatics found to be present, a total aromatic equivalent of 10.4 per cent is obtained.

Column 2 lists the percentages of benzene or kerosene

TABLE 4—AROMATIC EQUIVALENTS OF GASOLINES

Gasoline	Aromatic Equivalents Calculated from Analysis, Using 5 to 4 to 1 Ratio	Benzol Equivalents, Amount of Benzene Added to Straight-Run Mid-Continent *A*, Per Cent by Volume [b]	Aromatic Equivalents of Straight-Run Mid-Continent *A* Plus the Added Benzene, Using 5 to 4 to 1 Ratio
1–Straight-Run Mid-Continent, *A*	9.4	0	9.4
2–Straight-Run Mid-Continent, *B*	10.4	7	15.7
3–Special *A*	14.5	30	35.6
4–Motor *A*	15.3	18	25.7
5–Special *B*	17.5	20	27.5
6–Special *C*	18.1	40	45.7
7–California	15.7	35	41.1
8–Straight-Run Pennsylvania	4.2	3 [a]	...
9–Motor *C*	6.2	17 [a]	...
10–Untreated from Pressure-Still Distillate, *A*	27.2	35	41.1
11–Treated from Pressure-Still Distillate, *B*	26.9	30	36.6
12–Cracked Smackover	29.5	23	30.2
13–Motor *B*	23.7	20	27.5
14–Cracked Mid-Continent	24.6	28	34.7
15–Untreated from Pressure-Still Distillate, *C*	29.2	30	36.6
16–Untreated from Pressure-Still Distillate, *D*	29.2	25	32.0
17–Cracked Pennsylvania	20.7	19 [a]	...
18–Vapor-Phase Cracked	53.7	48	52.9

[a] Kerosene added.

[b] The general correctness of most of these figures for gasolines, Nos. 1 to 9, at a somewhat higher compression-ratio, has been established by H. G. Smith at Port Arthur, Tex.

TABLE 3—ANALYSIS OF SYNTHETIC GASOLINES

Gasoline	Percentage: Olefins Synthetic	Olefins Found	Aromatics Synthetic	Aromatics Found	Naphthalenes Synthetic	Naphthalenes Found	Paraffins Synthetic	Paraffins Found
17—Cracked Pennsylvania	11.7	8.0	16.7	15.3	6.7	9.0	65.0	67.7
14—Cracked Mid-Continent	15.0	18.2	18.5	13.9	12.6	13.5	53.9	54.3
18—Vapor-Phase Cracked	29.5	...	44.7	...	12.4	...	13.4	...
1—Straight-Run Mid-Continent *A*	2.8	...	3.9	...	19.7	...	73.6	...

TABLE 5—AROMATIC EQUIVALENTS OF GASOLINES

Gasoline	Aromatic Equivalents Calculated from Analysis, Using 2 to 2 to 1 Ratio	Benzol Equivalents, Amount of Benzene Added to Straight-Run Mid-Continent *A*, Per Cent by Volume	Aromatic Equivalents of Straight-Run Mid-Continent *A* Plus the Added Benzene, Using 2 to 2 to 1 Ratio
1–Straight-Run Mid-Continent, *A*	15.1	0	15.1
2–Straight-Run Mid-Continent, *B*	16.0	7	21.1
3–Special *A*	19.7	30	40.6
4–Motor *A*	21.0	18	30.4
5–Motor *B*	24.4	20	32.1
6–Special *C*	26.2	40	49.1
7–California	24.2	35	44.8
8–Straight-Run Pennsylvania	8.7	3 [b]	...
9–Motor *C*	10.5	17 [b]	...
10–Untreated from Pressure-Still Distillate, *A*	35.5	35	44.8
11–Treated from Pressure-Still Distillate, *B*	35.3	30	40.6
12–Cracked Smackover	37.5	23	34.7
13–Motor *B*	30.8	20	32.1
14–Cracked Mid-Continent	32.3	28	38.9
15–Untreated from Pressure-Still Distillate, *C*	37.8	30	40.6
16–Untreated from Pressure-Still Distillate, *D*	37.4	25	36.4
17–Cracked Pennsylvania	25.9	19 [b]	...
18–Vapor-Phase Cracked	65.6	48	55.9

[b] Kerosene added.

mixed with the standard gasoline to make the mixture equivalent in degree of detonation to the gasoline under test.

Column 3 shows the total aromatic equivalents of the mixtures made to balance each gasoline on engine test. Each figure includes the benzene actually mixed with the standard, plus the aromatic equivalent calculated from the analysis for the proportion of the standard gasoline present. For example, gasoline No. 13 required 20 per cent of benzene mixed with the standard fuel, gasoline No. 1, for balance. Since only 80 per cent of the standard fuel was present in the mixture, the aromatic equivalent of only this 80 per cent should be considered. Therefore, we have $15.1 \times 0.8 = 12.1$. This plus $20.0 = 32.1$, the aromatic equivalent of the mixture.

Experiments with Hydrocarbons

In view of the difference between the apparatus used by Ricardo and that employed in the present work, and because of some uncertainty as to the hydrocarbons studied by Ricardo, it was decided to make experiments on the methyl cyclohexane, hexylene and toluene already mentioned. Two series of tests were made, one by adding each hydrocarbon in turn to gasoline No. 1, the straight-run Mid-Continent standard and the other by adding the same proportions of each to gasoline No. 4, an average motor-gasoline. The same results were obtained with both fuels, indicating that 2 per cent of hexylene, an unsaturated hydrocarbon, and 2 per cent of methyl cyclohexane, a naphthene, gave the same effect as 1 per cent of toluene, an aromatic. These results were duplicated in several series of tests with different carbureting equipments, and were carefully checked further by a somewhat elaborate series of intercomparisons.

It should be remembered that hexylene probably gave greater reduction than would have been obtained with heptylene, which has a higher boiling-point; about the same as toluene and methyl cyclohexane. It is not believed that the difference would have been great enough to change the nature of the results. In general, these tests are regarded as indicating a 2 to 2 to 1 equivalence at a 5.5 to 1.0 compression-ratio in the engine used for this work. This conclusion must be limited further by the possibility that most petroleum naphthenes may be pentamethylene derivatives rather than hexamethylenes, to which class the methyl cyclohexane used belongs.

In view of the difference between the two sets of equivalents, the new ratio was used in a recalculation of the aromatic equivalents of the gasolines studied, and the new comparisons are given in Table 5.

When the results from the analyses, using both sets of equivalents, are compared with the results of actual engine-tests it is seen that, while both give somewhat wide deviations from the engine tests, the 2 to 2 to 1 ratio seems to give slightly better agreement than the 5 to 4 to 1 ratio. This is particularly true in the group of cracked Mid-Continent products, gasolines Nos. 10 to 16. From the results, it might be said that considerable additional information is needed before a definite conclusion can be reached.

It is pointed out in a communication from H. G. Smith of Port Arthur, Tex., that the value of the ratio might be expected to change with each change in operating compression and temperature, and that, in general, the lower the compression used is, the nearer would the equivalent values for naphthenes and olefins approach that for aromatics.

Accuracy of Previous Tests

To check the accuracy of the previous engine-tests, the entire set of measurements was repeated, using as a standard gasoline No. 4, an average motor-gasoline having better non-detonating characteristics than those of the first standard, gasoline No. 1. The relation between the two sets of measurements is shown in Fig. 2, where the percentage of benzene or kerosene required for each gasoline is presented graphically. This chart was constructed by arranging the benzol equivalents for the gasolines, measured against gasoline No. 1 as standard,

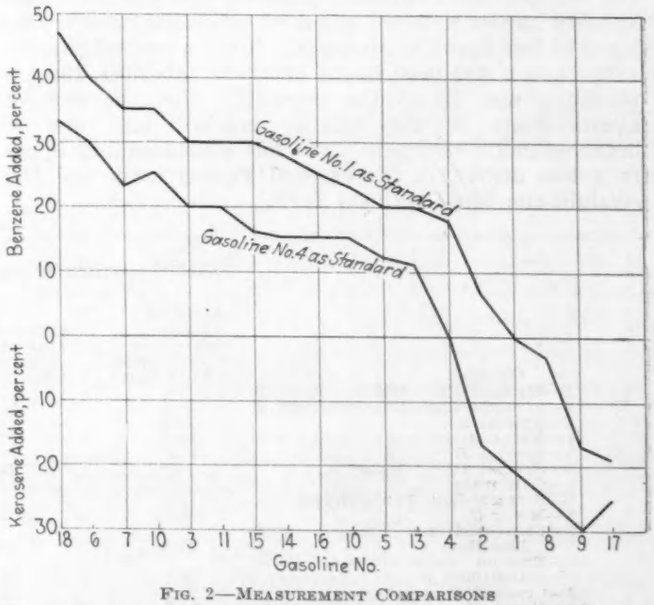

Fig. 2—Measurement Comparisons

To Check the Accuracy of the Previous Engine-Tests, the Entire Set of Measurements Was Repeated, Using as a Standard Gasoline No. 4, an Average Motor-Gasoline Having Better Non-Detonating Characteristics Than Those of the First Standard, Gasoline No. 1. The Relation between the Two Sets of Measurements Is Shown, the Percentage of Benzene or Kerosene Required for Each Gasoline Being Presented Graphically. Despite the Irregularities, It Is Believed That the Degree of Concordance, as Indicated by the General Parallelism of the Curves, Is Entirely Satisfactory

in the order of decreasing benzol value, and then plotting the benzol equivalents obtained against gasoline No. 4 as standard, in the same order. While there are a few irregularities, it is believed that the degree of concordance, as indicated by the general parallelism of the graphs, is entirely satisfactory.

For the sake of completeness, a table comparing the analyses with the engine tests, using gasoline No. 4 as standard, was compiled, as was done for gasoline No. 1 in Tables 4 and 5. These comparisons are given as Table 6. The general facts and the comparison of the 5 to 4 to 1 and the 2 to 2 to 1 ratios are not greatly changed by these figures, the conclusions being as indicated by the data in Tables 4 and 5, where the harder-knocking standard, gasoline No. 1, was used. It may be well to emphasize the somewhat obvious fact, brought out in Fig. 2 and in Table 6, that the quality of the standard fuel employed will affect the agreement between analyses and engine tests materially. The use of a standard of less detonating tendency will increase the number of gasolines requiring the addition of kerosene to the standard for balance, while the aromatic equivalent, determined by analysis, will remain the same.

Synthetic Gasolines

The mixtures of pure hydrocarbons listed in Table 3 were also tested in the engine. The results are given in Table 7. No benzene-balance figures were determined, and Table 7 gives only the indicator readings of the mixtures and the natural gasolines, both against the standard fuel.

The results with the pure hydrocarbon mixtures, given in Table 7, indicate that the composition of commercial gasolines is far more complex than might be assumed from the classification given by the method of analysis discussed. It will be noted that the one case of satisfactory agreement between synthetic and natural fuels occurred in the case of a mixture, vapor-phase cracked, containing only 13 per cent of paraffins. In the case of the cracked Mid-Continent gasoline, the synthetic fuel knocked harder than the standard, while the natural fuel knocked less than the standard. Since a normal paraffin hydrocarbon was used in the synthetic mixtures, the explanation may lie in the possibility that the paraffin hydrocarbons in the natural, cracked fuel are of branched-chain structure. The like considerations apply in a less degree to the cracked Pennsylvania and the straight-run Mid-Continent fuels.

TABLE 7—COMPARISON OF SYNTHETIC AND PETROLEUM GASOLINES

Gasoline	Indicator Reading Using Motor Gasoline *A* as Standard: Synthetic	Petroleum
17—Cracked Pennsylvania	20–50	20–35
14—Cracked Mid-Continent	20–40	20–12
18—Vapor-Phase Cracked	20–4	20–3
1—Straight-Run Mid-Continent *A*	20–45	20–33

Influence of Volatility

It is generally recognized that, with an increase in boiling-point—molecular weight—within a series of hydrocarbons, there is an increasing tendency to detonation. In the absence of published data on the magnitude of this effect for fractions of commercial gasolines, it was decided to study the influence of volatility. Gasoline No. 2, a straight-run Mid-Continent product, was fractionally distilled through a Glinsky column, 18-deg. fractions being collected. Mixtures were made containing 75 per cent of the original gasoline and 25 per cent of successive fractions. These were assayed by the distillation method used by the American Society for Testing Materials and were subjected to detonation test against the original gasoline as standard. Distillation curves for the most significant mixtures are given in Fig. 3.

As can be seen from Table 8, the intensity of detonation increases almost regularly with rise in boiling-point. The slight irregularities are definite and are attributable to possible accumulation of non-detonating hydrocarbons in certain fractions. The distillation curves show the gasolines to fall into two overlapping groups. In the first, the curves are approximately the same up to about the 40-per cent point, above which they diverge, the detonation characteristics for the individual fuels being also different. In the second group the end-points are essentially the same, within 10 deg., but the middle portions of the curves and the detonating tendency again differ. The middle ranges of the curves for all the mixtures seem to be the most significant, and the influence of volatility for this gasoline and its mixtures is as it has generally been supposed to be.

Discussion of Results

Regarding engine tests with gasoline No. 1, as standard, which is a comparatively hard-knocking fuel, it will

TABLE 6—AROMATIC EQUIVALENTS OF GASOLINES

Gasoline	Aromatic Equivalents from Analysis, Using 5 to 4 to 1 Ratio	Aromatic Equivalents from Analysis, Using 2 to 2 to 1 Ratio	Benzol Equivalents, Amount of Benzene Added to Motor Gasoline *A*, Per Cent by Volume	Aromatic Equivalents of Motor Gasoline *A* Plus the Added Benzene Using 5 to 4 to 1 Ratio	Aromatic Equivalents of Motor Gasoline *A* Plus the Added Benzene Using 2 to 2 to 1 Ratio
1—Straight-Run Mid-Continent *A*	9.4	15.1	21[c]	...	...
2—Straight-Run Mid-Continent *B*	10.4	16.0	17[c]	...	...
3—Special *A*	14.5	19.7	20	32.2	36.8
4—Motor *A*	15.3	21.0	0	15.3	21.0
5—Special *B*	17.5	24.4	12	25.5	30.5
6—Special *C*	18.1	26.2	30	40.7	44.7
7—California	15.7	24.2	23	34.8	39.2
8—Straight-Run Pennsylvania	4.2	8.7	25[c]	...	...
9—Motor *C*	6.2	10.5	30[c]	...	...
10—Untreated from Pressure—Still Distillate *A*	27.2	35.5	25	36.5	40.7
11—Treated from Pressure—Still Distillate *B*	26.9	35.3	20	32.2	36.8
12—Cracked Smackover	29.5	37.5	15	28.0	32.6
13—Motor *B*	23.7	30.8	11	24.6	29.7
14—Cracked Mid-Continent	24.6	32.3	15	28.0	32.6
15—Untreated from Pressure—Still Distillate *C*	29.2	37.8	16	28.8	33.6
16—Untreated from Pressure—Still Distillate *D*	29.2	37.4	15	28.0	32.6
17—Cracked Pennsylvania	20.7	25.9	25[c]	...	...
18—Vapor-Phase Cracked	53.7	65.6	33[c]	43.25	47.1

[c] Kerosene added.

TABLE 8—ENGINE TESTS ON INFLUENCE OF VOLATILITY

75 Per Cent of Gasoline No. 2 and 25 Per Cent of Fractions Distilling Between Deg. Fahr.	Indicator Reading
104–140	20–10
140–158	20–8
158–176	20–10
176–194	20–14
194–212	20–17
212–230	20–20
230–248	20–20
248–266	20–21
266–284	20–23
284–302	20–25
302–320	20–22
320–338	20–24
338–356	20–25
356–374	20–29
374–392	20–32
392–410	20–32
410–428	20–34
428–up	20–34

be seen that, in the range of cracked Mid-Continent gasolines, Nos. 10 to 16, the method of Egloff and Morrell gives moderately fair agreement. However, discrepancies appear as soon as materials of widely different types are examined. Attention is called to gasoline No. 3 which, in the engine, balanced a mixture of 30 per cent of benzene and 70 per cent of standard fuel, equivalent to 36 per cent of aromatics by the Egloff and Morrell method of calculation, although its aromatic equivalent by their method of analysis is only 14 per cent. A similar condition is shown by gasoline No. 6, which balanced a 40-60 mixture of benzene and standard fuel, equivalent to 45 per cent of aromatics, although the Egloff and Morrell aromatic equivalent, by analysis, is only 18 per cent. A similar condition is shown by gasoline No. 7, an uncracked California distillate.

When gasolines of similar composition as shown by analysis are considered, further differences appear. The most outstanding case is that of gasolines Nos. 1 and 3, which correspond closely in analysis and in calculated aromatic equivalent, the latter differing by only 5 per cent; the engine tests of which, however, show that gasoline No. 1 is hard-knocking and gasoline No. 3 ranks well as an antiknock fuel. Comparison of gasoline No. 17, Pennsylvania cracked, and gasoline No. 9, a commercial motor-gasoline, brings out the fact that they have about the same knocking tendency, although they are strikingly different in composition and calculated aromatic equivalent. The reverse is shown by gasolines Nos. 8 and 9, which have fairly close calculated aromatic equivalents but widely different knocking tendency. It should be noted, however, that the Egloff and Morrell method of analysis and calculation gives very satisfactory agreement with the engine tests in the case of gasoline No. 18, vapor-phase cracked, which, as will be seen, contains only 13 per cent of paraffins.

Concerning engine tests with gasoline No. 4, which is a comparatively light-knocking fuel, a good average motor-gasoline of only moderate detonating tendency, as standard, certain differences were observed when the tests were repeated. In the group of cracked Mid-Continent products, gasolines Nos. 10 to 16, the agreement is still moderately fair. With this standard, the agreement is better for gasolines Nos. 3, 6 and 7 than with the first standard, though not satisfactory; but it is much worse for gasolines Nos. 8 and 9, which have small aromatic equivalents by analysis but require 25 and 30 per cent of kerosene respectively for balance. Another interesting case is that of gasolines Nos. 8 and 17, which require the same amount, 25 per cent, of kerosene for balance, but differ widely in their aromatic equivalents calculated from analysis. For a comparison in the group of fuels requiring benzene for balance, gasolines Nos. 6 and 18 are noted. They have almost the same aromatic equivalent by engine test, 30 and 33 per cent respectively, but the analysis indicates aromatic equivalents of 18 and 53 per cent respectively.

Influence of Volatility

The tests on the influence of the volatility of gasoline, as has been stated, favor the general belief that increase in boiling-point in one general type of petroleum distillate tends to increase detonation. A recent case has come to our attention, in which it was stated that a group of gasolines differing in end-point by as much as 40 deg. fahr. were found to have the same detonation value. While it undoubtedly is possible to obtain gasolines of different end-point but of the same detonating tendency, the above experiment shows that it is also possible to produce gasolines of the same end-point but of widely different detonating tendency. After all, the end-point for a motor fuel is only slightly related to its over-all volatility, the intermediate ranges being the more important.

Influence of Standard

Various laboratories have used as standards gasolines resembling in knocking value gasoline No. 1 of the present series. The use of such a standard may serve to bring out differences in knocking tendency better than the use of a lighter knocking standard, such as gasoline No. 4, but it makes possible also certain misleading conclusions, particularly when the benzol equivalent scale is employed. It is the experience of various investigators that the degree of knock reduction is not directly proportional to the percentage of benzene present. In other

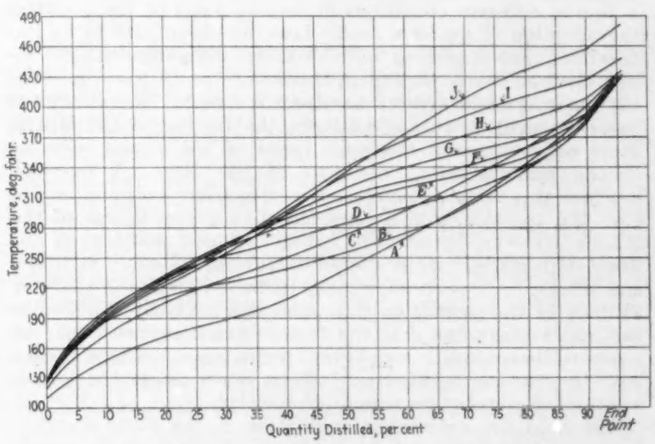

FIG. 3—INFLUENCE OF VOLATILITY

Gasoline No. 2, a Straight-Run Mid-Continent Product, Was Fractionally Distilled, 18-Deg. Fractions Being Collected. Mixtures Were Made Containing 75 Per Cent of the Original Gasoline and 25 Per Cent of Successive Fractions. These Were Assayed and Were Subjected to Detonation Test against the Original Gasoline as Standard. Distillation Curves Are Shown for the Most Significant Mixtures, the Data for Which Are as Follows:

Curve	Fraction, Deg. Fahr.	Engine Test
A	158 to 176	20—10
B	230 to 248	20—20
C	Original	20—20
D	284 to 302	20—25
E	320 to 338	20—24
F	338 to 356	20—29
G	356 to 374	20—29
H	374 to 392	20—32
I	410 to 428	20—34
J	428 and Up	20—34

words, a fuel containing 20 per cent of benzene is not necessarily half as good as one containing 40 per cent of benzene. Therefore, a result giving a 25-per cent benzol equivalent against gasoline No. 1 as standard, need not indicate that the fuel in question will function as a satisfactory antiknock gasoline when used in an automobile. The same fuel tested against gasoline No. 4 as standard will give about a 15-per cent benzol equivalent. Since gasoline No. 4 represents merely a good average commercial motor-gasoline, the latter figure better indicates the actual value of the fuel under test. Since most real antiknock gasolines are sold at a premium over ordinary-motor-gasoline prices, they should give marked improvements over ordinary-motor-gasoline performance. Examination of the results in Column 3 of Table 6, where gasoline No. 4 is used as standard, will show that a number of the cracked gasolines studied cannot be regarded as satisfactory antiknock gasolines when judged on this basis. These results do show, however, that motor fuels of satisfactory antiknock value, composed entirely of petroleum, are available to consumers. To this extent it is believed that the gradual introduction of engines having higher compression will not be attended by any serious difficulty.

SUMMARY

We do not know of any dependable method for determining the detonating tendency of motor fuels except that of direct engine tests.

We have found a ratio for knock-reducing tendency of a naphthene, an olefin and an aromatic hydrocarbon differing from that indicated by the work of Ricardo. The subject deserves complete investigation.

Evidence has been presented for the general belief that the detonating tendency of gasoline fractions increases with rise in boiling-point.

While it is probable that cracking offers the readiest way for most petroleum refiners to produce motor fuels of improved antiknock value from petroleum, it does not follow necessarily that all cracked gasolines constitute satisfactory antiknock motor-fuels, as has been clearly shown; many do not.

The results obtained by the use of different standard fuels indicate the desirability of an agreement as to detonation standards.

We wish to acknowledge the valuable assistance of W. H. Ragsdale, J. O. Timms and E. C. Martin, of Mellon Institute, Pittsburgh, in the carrying out of the experimental work we have reported.

UNIFORM STATE MOTOR-VEHICLE LAWS

HOW can the large number of motor-vehicle operators who drive in several States be held to the strictest accountability for their acts if the laws and regulations under which they operate are so diverse and complicated that it is practically impossible for any one to know them thoroughly? To say that the motorist is responsible and should inform himself of the laws and regulations wherever he may happen to be is all very well, but, as a practical matter, this is often impossible. The obvious solution of the difficulty lies in uniformity as between the various States and cities.

Due to different conditions in various parts of the Country, the adoption of uniform traffic laws has been said to be impossible; that American individualistic temperament will insist upon as much variety in these laws as in those governing marriage and divorce has been stressed. The statement has been made that, for example, the farmer of the Middle West will not accept the same types of law as are required in the manufacturing districts of the East. I question whether this view is correct. Recently I had occasion to discuss the question with a representative group in one of the Middle Western States. The group included members of the State legislature, farmers, manufacturers, railway operators, and others. All were unanimous in their agreement that the attitude of the farmer on this point has radically changed in the last 2 years and that the farmer has discovered that he needs modern vehicle legislation, including a driver's license law, for his own protection just as much as do the inhabitants of the larger centers of population.

The need for automobile regulation in the rural districts appears to be borne out by a survey of rural motor-vehicle fatalities recently carried on by the National Automobile Chamber of Commerce. This survey reported an increase of 23 per cent in fatalities in the rural districts in 1925 as compared with the preceding year, whereas the average increase for the whole Country, urban and rural, was 10 per cent. In other words, motor-vehicle accidents are increasing more rapidly in the country than in the cities. That the farmer should begin to appreciate this situation and participate in the program for correcting it is well.

The chief obstacle to the adoption of motor-vehicle legislation along the lines of the Uniform Vehicle Code is found in the desire of the different States to retain what they now have. That some reason for this desire exists is appreciated, for a law that has been tested in the courts has behind it, of course, an increased weight of authority. However, adopting carefully framed legislation, the provisions of which are based, as in the case of the Uniform Vehicle Code, mainly on successful experience in States where they have been tried out, possesses compensating advantages. If the Code were adopted it would not mean more laws; it should result in the elimination of undesirable laws; it should actually leave fewer laws, but those would be the essential ones worked out on a uniform basis.

And just one further word. You rightly conceive this as a problem affecting primarily the people of Michigan. It is, in fact, chiefly citizens of Michigan who are being killed or injured on your streets and highways. At the same time the other States of the Union have a very real interest in what you do in your State. In the first place, their people come to visit you and suffer or benefit according as you have or have not your traffic under safe control. In the second place, Michigan drivers are, to a constantly increasing extent, visiting other States, and those States with which you have reciprocity in use of the highways have a right to expect of you that you will maintain a high standard in barring from the highways those who are unable or unwilling to use them with safety to others. Furthermore, Michigan is always looked to as a leader in matters relating to the motor-vehicle. You took the lead with respect to the certificate of title law. You have taken the lead in respect to the uniform traffic ordinance. Legislatures of 44 States are meeting in 1927 and only 9 in the following year 1928, so that in many of the States if the opportunity is lost at this session 2 years or more will elapse before legislation can be enacted.—From an address by Col. A. B. Barber, manager of the transportation and communication department of the Chamber of Commerce of the United States of America and director of the National Conference on Street and Highway Safety.

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Why Does a Car "Pivot"?

By JOHANNES PLUM[1]

ANNUAL MEETING PAPER *Illustrated with* DIAGRAMS

ABSTRACT

REMARKING the difficulty of explaining logically the strange phenomenon known as the "pivoting" of a car, the author, after presenting citations of actual experiences with various combinations of front-wheel and rear-wheel braking and their tendencies to cause a car to pivot, analyzes pivoting and explains its causes under (*a*) "dry-roadway" and (*b*) "skiddy-roadway" conditions.

Concerning (*a*), the author states that when two-thirds of the braking force of a four-wheel-brake system is distributed to the *rear wheels*, the preponderance of the stopping or braking force will remain active to the rear of the center of gravity of the car, causing a so-called "drag-anchor" effect to counterbalance what is termed the "spin effect," and no dry-roadway pivot can occur. Since the friction available between the roadway and the tires is comparatively small on a skiddy roadway, the retarding forces at the two sets of wheels should be utilized to their utmost. Owing to the change of so-called "effective weight" from the rear wheels to the front wheels when the brakes are applied, the brakes on the latter will resist much greater pressure from the foot-pedal before the wheels lock than will the brakes on the rear wheels before the rear wheels lock. Consequently, a greater braking-force should be distributed to the *front wheels* than is supplied to the rear wheels. If two-thirds of the braking force from the foot-pedal is distributed to the *front wheels* for skiddy-roadway conditions, the author says that the front wheels always will lock momentarily before the rear wheels lock and that no pivoting can occur. He therefore concludes that for the two conditions, (*a*) and (*b*), under which a car is to be stopped, it is necessary to design a four-wheel-brake system that combines two different methods of appropriate distribution of the braking force because the requirements are so different.

VARIOUS theories are prevalent that purport to account for the strange behavior of a car under certain conditions, upon the application of its brakes. For instance, a car equipped with rear-wheel brakes only will almost always "pivot" on a slippery roadway when the brakes are applied violently. This will occur even when the car is traveling in an apparently straight course and, because of this fact, the public mind has developed an hypothesis that attempts to explain pivoting as the result of unevenly applied braking forces; that is, it is taken for granted that pivoting is due to what may be called a "twisting effect" caused by a braking force on one particular wheel that is greater than that on the other wheel. However, when this hypothesis is tested by experiment, it is found that the more unevenly the braking force is distributed between the right and the left rear-wheel, the less tendency the car has to skid.

Pivoting is a very strange phenomenon, and the more we try to apply logic to the solution of the problem, the more intricate it seems. In cases in which the braking force is applied only to the rear wheels, it apparently can be assumed that the friction between the rear wheels and the road helps to straighten out the car should it show a tendency to turn the rear end ahead of the front end. Nevertheless, at the very moment when the rear wheels lock, they begin to move faster over the road than do the front wheels, to which no decelerating force is applied, and the car executes a maneuver that is called "pivoting," an ordinary maneuver or pivot of this type being illustrated in Fig. 1. When the car shown in Fig. 1 stops, the braked and locked rear-wheels are found to be ahead of the unbraked front-wheels, with reference to the direction of car-travel, thus indicating that the rear wheels moved faster during the period of pivoting than the front wheels, in spite of the decelerating force that was applied to them.

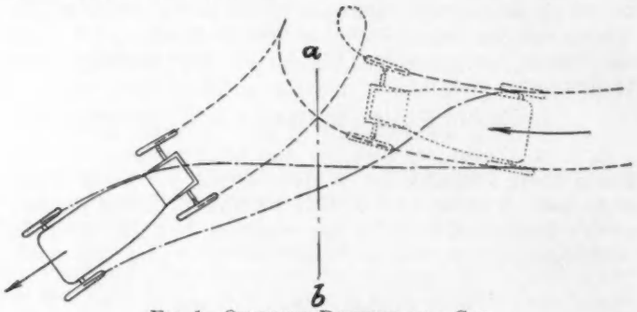


FIG. 1—ORDINARY PIVOTING OF A CAR
When the Car Stops, the Braked and Locked Rear-Wheels Are Found To Be Ahead of the Unbraked Front-Wheels, with Reference to the Direction of Car Travel, Thus Indicating That the Rear Wheels Moved Faster during the Period of Pivoting Than the Front Wheels Moved, in Spite of the Decelerating Force That Was Applied to Them

We have also to consider the strange effect of front-wheel brakes on pivoting when they are used in addition to rear-wheel brakes. In spite of the greater magnitude of the decelerating forces applied, on the average, with four-wheel brakes, the likelihood of pivoting seems more remote than with rear-wheel brakes only. Naturally, this fact has produced a belief that the front-wheel brakes diminish the pivoting force, whatever this force may be. It is apparently logical to believe that because the front wheels are turned at an angle and are inclined toward the center of the curve along which the car is traveling, the decelerating forces applied will have a direction that will counteract any rotary motion of the car. However, in some instances, especially for emergency stops, four-wheel brakes may cause a pivot exceedingly more violent than might occur with rear-wheel brakes only. Those who have had this experience sincerely believe that the front-wheel brakes increase the pivoting force; therefore, they disconnect them.

In other instances four-wheel brakes may cause a very slow pivoting, in a similar manner to that in which the decelerating forces at the front wheels were acting against the pivoting force. Last, but not least, a car equipped with four-wheel brakes may pivot even on a dry hard-surfaced road. Such pivoting is very unlikely when a car is equipped with rear-wheel brakes only, and it is therefore apparently logical to suppose that front-wheel brakes in themselves are creating a pivoting force.

[1] In care of the Royal Danish Legation, City of Washington.

But if a car is equipped with front-wheel brakes only, the car will not pivot under any condition!

Why a Car Can Be Steered

From the resume just given of various experiences with pivoting, no legitimate explanation of its cause can be developed. Let us therefore disregard these experiences and consider instead why a car does not always pivot; or, in other words, why a car can be steered.

A car can be steered in a definite direction with respect to a fixed center of turning when its wheels rotate continuously in a direction at right angles to their respective shafts. When a condition exists in which this principle of motion is lacking, the car is either pivoting or sliding. When any wheel locks, it thereupon ceases to function as a wheel and no longer influences the direction of the car. Under such a condition we may say that the wheel has lost what I term the "sense of direction" which it formerly had and that it will move in whatever direction the forces acting upon it may cause it to move, even though these forces may not arise at the wheel itself. In other words, before the wheels lock, the forces arising at the wheels are causing the car to move as already defined, while, after locking, the wheels become incorporated solidly with the car and, to all intents and purposes, the car is then mounted upon rubber-covered skids.

Frictional Force Available for Stopping

Let us, therefore, consider the total amount of frictional force available for a given wheel, when the wheel is locked. The amount of this force will be the product of the downward force of the wheel on the road and the coefficient of friction between the tire and the road.

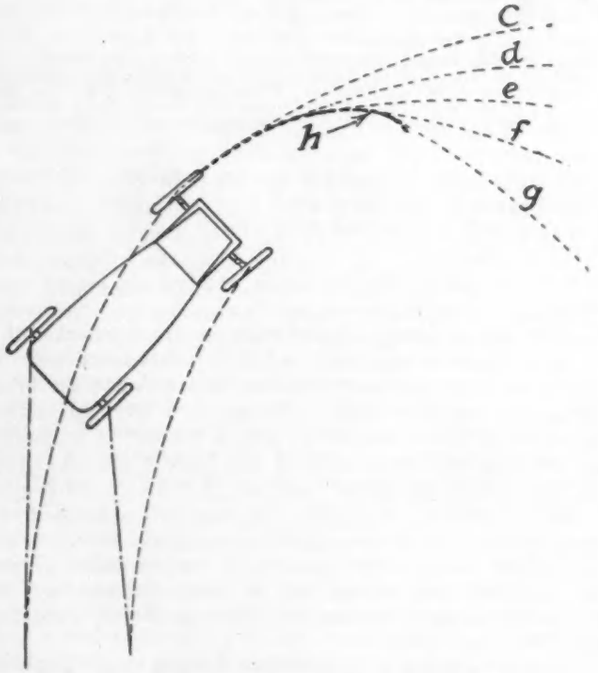


Fig. 2—Car Pivoting on a Curve

Considering a Car Equipped with Rear-Wheel Brakes Only, the Car Being in Motion on a Curve, When the Brakes Are Applied with Sufficient Force To Lock the Rear Wheels, the Rear End of the Car Tends To Follow a Tangent to the Curve While the Front End, Guided by the Freely Revolving Front-Wheels, Will Continue To Move on a Curve Which Is Then of Shorter Radius Than the Curve Originally Followed. The Curves *c*, *d*, *e*, *f*, and *g* Represent the Courses Followed by the Front Wheels at a Number of Successive Instants After the Pivoting Movement Begins. The Front End of the Car Is, in Effect, Being Pointed toward a Continuously Sharper and Sharper Curve, *h*, with the Tendency To Rotate or Pivot Aggravated at Each Successive Increment of Pivoting, Even Though the Car Speed Be Lessened

Whatever part of this total amount is used in a given direction must be subtracted from the total amount to find the amount available for use in any other direction. In addition, we have the complication that there is a great difference in the application of these facts to "dry" and to "skiddy" conditions of the roadway. In the former case, the coefficient of friction between tire and road remains essentially constant with speed; in the latter case, the coefficient of friction between tire and road drops rapidly as the speed of the tire increases with respect to the road.

Why a Car Pivots

Considering a car equipped with rear-wheel brakes only, the car being in motion on a curve, when the brakes are applied with sufficient force to lock the rear wheels, with consequent loss of sense of direction to these wheels, the rear end of the car tends to follow a tangent to the curve of direction while the front end, guided by the freely revolving front-wheels, will continue to move on a curve which is then of shorter radius than the curve originally followed. Fig. 2 illustrates the movement that apparently would take place under the condition described; that is, as if the motions of the front end and of the rear end took place separately. Actually, the curves *c*, *d*, *e*, *f*, and *g* represent the courses followed by the front wheels at a number of successive instants after the pivoting movement begins. The front end of the car is, in effect, being pointed toward a continuously sharper and sharper curve, *h*, with the tendency to rotate or pivot aggravated at each successive increment of pivoting, even though the car speed be lessened. Fig. 1 shows the actual path of the car in a complete turn about its own axis, following the commencement of the pivot movement described; it is merely illustrative of the principles involved and is not intended to show the exact tracks of the wheels.

Total Wheel-Friction on the Road

Let us now link together some of our observations concerning total wheel-friction and the action of a car with rear wheels locked and front wheels free to turn; introducing at the same time a new idea, namely, that a car rarely, if ever, travels continuously for any appreciable length of time in a perfectly straight course, considered mathematically. This idea supplies us with a clue as to what may actually start the pivoting movement.

When the rear wheels are locked, the total road-friction available at the locked wheels is being absorbed in retarding the car. Then, any transverse force, however small, will be sufficient to produce motion in another direction. Here, then, is the germ of the idea which supplies the explanation for the commencement of pivoting when, apparently, the car is traveling in a perfectly straight course. As previously described, as quickly as this pivot motion commences, the pivoting forces quickly build up and a full-grown skid results. The centrifugal force acts at right angles to the direction of motion of the car. The transverse resistance of the tires prevents any sidewise movement until the wheels are locked. But, at the instant that the transverse resistance becomes equal to any other resistance in magnitude, sidewise motion follows. Of course, if the speed is sufficiently high and the curve is sufficiently sharp, a movement entirely analogous to that just described will result, in spite of the fact that the rear wheels may be revolving.

Balancing of Forces

It might seem that if the foregoing explanation held for slippery or skiddy roadways, the same action would

occur on dry roadways. If the speed be high enough so that the interval of time between the commencement of the deceleration and the complete stopping of the car is long, a pivot will result. But it must be considered that when the deceleration is large there will be a balance between the tendency of the centrifugal force to be increased, due to the successively decreasing ratio of curvature, and the tendency for the centrifugal force to be lessened, due to the rapid decrease in velocity. To illustrate this point, let us examine the mathematical expression for centrifugal force expressed as the relation:

$$\text{Centrifugal force} = (v^2/r)\ m \qquad (1)$$

where

m = the mass
r = the turning radius
v = the velocity

It can be seen that, if v and r both change, their rates of change may be such with respect to each other that the centrifugal force would grow either larger or smaller. On a skiddy roadway, the rate of change of velocity is comparatively small, while the rate of change of r may be large; the reverse may be true under dry-roadway conditions.

Brake Equalization

In the foregoing discussion it has been more or less tacitly assumed that the brakes have been equalized. It is obvious that the more unequal the braking adjustment may be, the more difficult it becomes to lock both wheels simultaneously. Consequently, there will be a comparatively large amount of transverse tractive-resistance available at the rolling wheel for resisting the pivoting force. It is true that, as long as there is a difference between the right-hand retarding-force and the left-hand retarding-force, unequal brake-adjustment will create a twisting effect with a tendency to effect sidewise motion of the rear end of the car. The twisting effect is, however, counteracted by the sense of direction of the rolling wheel. When both wheels are locked, it is immaterial which one of the two brakes receives the greater pressure.

Pivoting with Four-Wheel Brakes

Let us now consider the effect on pivoting when front-wheel brakes are used in addition to rear-wheel brakes. It is obvious that, if the brakes are identical in braking force with those previously considered, a given pressure upon the foot-pedal, when distributed to all four wheels, will not lock any one of the wheels as readily as did a concentrated pressure distributed between only two wheels. Consequently, the likelihood of pivoting is more remote with four-wheel brakes than with rear-wheel brakes only.

To understand the action of four-wheel brakes fully, let us consider the effect of weight transfer from the rear wheels to the front wheels during the deceleration. For instance, with a car in which the braking system is designed to use 50 per cent of the braking force on the rear wheels and 50 per cent on the front wheels, as soon as the car begins to decelerate, the effective weight of the rear end of the car becomes less and the effective weight of the front end becomes greater. The tractive force available at the rear end and at the front end respectively is changed in proportion to these changes of effective weight; consequently, if any wheels lock, the rear wheels will lock first and, thereafter, the 50-50-per cent braking relation no longer holds. Furthermore, it must be remembered that on a skiddy roadway there is the complication that the coefficient of friction between the tire and the road drops instantaneously with the locking of the wheel; therefore, simultaneously with the locking of the rear wheels on a slippery roadway, the 50-50-per cent braking relation becomes null and void.

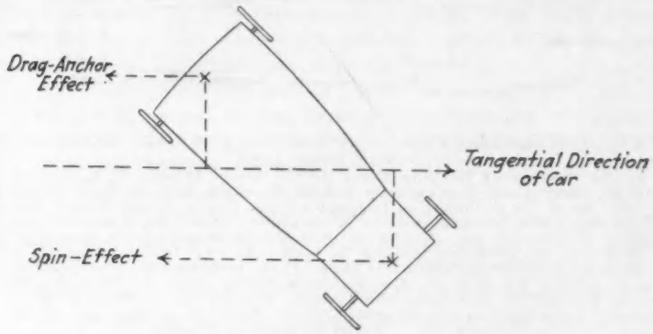


Fig. 3—Forces That Act During Pivoting

"Spin Effect" Is a Force Produced Only by the Application of Retarding Forces at the Front of the Car. It Is the Tendency of the Car To Rotate in a Horizontal Plane About the Center Point of the Front Axle. The "Drag-Anchor Effect" Is a Force Opposed to the Spin Effect and Is Produced by Applying Retarding Forces at the Rear End of the Car. Until the Rear End of the Car Is Displaced toward the Outside of the Curve, the Drag-Anchor Effect Probably Is Superimposed on the Ordinary Pivoting Force; But After Such Displacement the Drag-Anchor Effect Tends To Counteract the Pivoting Force

"Spin Effect" and "Drag-Anchor Effect"

A new force, entirely different from any previously discussed, must be considered and I will term it the "spin effect." The spin effect is the tendency of the car to rotate in a horizontal plane about the center point of the front axle, as shown in Fig. 3, due to the action of the front-wheel brakes. That is, it is an effect produced only by the application of retarding forces at the front of the car. The force is produced by a moment that is the product of the displacement of the center point of the front axle from the tangential direction of the car and the component of the decelerating force at the front end. Until the front end of the car becomes displaced toward the inside of the curve, the spin effect probably is zero. After this displacement, however, the spin effect accumulates, becoming in itself a pivoting force of great magnitude which is superimposed on the ordinary pivoting force.

It is obvious that a force closely related to the spin effect is produced by applying retarding forces at the rear end of the car. This force I term the "drag-anchor effect." Until the rear end of the car is displaced toward the outside of the curve, the drag-anchor effect probably is superimposed on the ordinary pivoting force. This is readily understood when it is remembered that, on a curve, the tracks of the rear wheels are always inside the tracks of the front wheels. After this displacement, however, the drag-anchor effect tends to counteract the pivoting force. It is thus seen that the spin effect and the drag-anchor effect are diametrically opposed forces; but it must be remembered that, when and after the rear wheels are locked, the spin effect increases proportionally with the magnitude of the deceleration force, or the transfer of effective weight to the front wheels, while the drag-anchor effect decreases proportionally with the deceleration force. Therefore, only a fraction of the total braking-force can be applied to the front wheels, if it should be desirable to counterbalance the spin effect with the drag-anchor effect. The importance of this fact will be explained later.

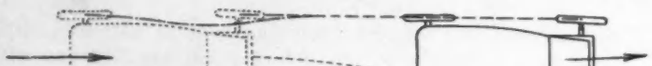


FIG. 4—MOMENTARY LOCKING OF THE FRONT WHEELS BEFORE THE REAR WHEELS LOCK

If the Amount of Braking Force on the Front Wheels Is Increased Until They Lock Momentarily before the Rear Wheels Lock, They Will Tend To Follow the Tangent of the Curve Along Which the Car Has Been Moving and the Momentarily Revolving Rear-Wheels Will Follow in the Tracks of the Front Wheels, Consequently, Although the Steering Ability Is Lost, the Car Is Traveling in a More Nearly Straight-Ahead Course Than It Would Be Possible for Any Driver To Steer It, But Steering Ability Can Be Regained at Any Instant by Releasing the Brakes, This Being in Striking Contrast to the Inability To Regain Control of the Car Under All Other Conditions Created by Locked Wheels

FRONT-WHEEL LOCKING AFTER REAR WHEELS LOCK

Many drivers show a preference for the old method of braking on the rear wheels only and give as a reason that, if the front wheels become locked, the driver is "lost" as he then has no chance of correcting the skid by the aid of the steering-wheel. Let us see how this hypothesis arises.

For example, considering a system in which the braking force is equally distributed to the two sets of wheels, front and rear, owing to the transfer of effective weight to the front wheels from the rear wheels, the latter will lock long before the front wheels lock. As already pointed out, at the very moment that the rear wheels lock, the coefficient of friction between the rear-wheel tires and the road drops rapidly and the wheels also lose their sense of direction. The spin effect exceeds the drag-anchor effect considerably, and the exact condition needed to cause the most violent skid is then created. In this case the car will skid out instantaneously until it has a sidewise position and, as soon as the car is in this position, the front wheels are no longer in front. Consequently, the effect of weight transfer to the front wheels decreased toward zero during the period of the pivoting, and the front wheels will now lock just as readily as the rear wheels lock. The car will then slide sidewise with all four wheels locked and the trouble is that, even if the driver should ease the pressure on the foot-pedal, no one of the wheels, when sliding sidewise, will have any tendency to regain its rotation and its sense of direction; consequently, the driver feels, and also is, completely "lost" until the car comes to a stop.

INCREASE OF FRONT-WHEEL BRAKING-FORCE

Let us now consider the effect of increasing the amount of braking force on the front wheels. From the foregoing reasoning it follows that, at least up to the point at which the front wheels lock simultaneously with the rear wheels, the spin effect will be increased proportionally; therefore, the pivoting may become more and more violent up to this point. However, exactly at the point at which the front wheels lock simultaneously with the rear wheels, the action is different. The effect of the pointing of the car toward curves of successively shorter radius, as described in connection with Fig. 2, will not occur, inasmuch as this effect is contingent upon the rolling of the front wheels. When locked, the front wheels manifestly cannot take the car into sharper and sharper curves; consequently, any pivoting that occurs will be very slow in comparison with all pivoting that occurs when the front wheels are rolling. But if we continue to increase the amount of braking force on the front wheels until they lock momentarily before the rear wheels lock, they will tend to follow the tangent of the curve along which the car has been moving and the momentarily revolving rear-wheels will follow in the tracks of the front wheels. Consequently, as indicated in Fig. 4, although the steering ability is lost, the car is traveling in a more nearly straight-ahead course than it would be possible for any driver to steer it, and the car will continue straight ahead thereafter, even though the rear wheels be subsequently locked.

It is of great interest to note that, in addition to the lack of pivoting under the condition just described, steering always can be regained at any instant by releasing the brakes, this being in striking contrast to the inability to regain control of the car under any of the conditions described previously. With front-wheel brakes only, the action is similar to the condition just described, except that, in this instance, there can, of course, be no locked rear-wheels. Consequently, a pivot cannot occur which is due to the braking action.

"DRY-ROADWAY PIVOT"

The skidding accidents caused on wet roadways are the only ones with which the public is at all familiar. But the more general adoption of four-wheel brakes has brought a new type of accident which I term the "dry-roadway pivot." In describing such accidents, eye witnesses attempt to explain them by saying that the car turned a somersault owing to a locking of the front wheels by the brakes. It must be admitted that, very frequently, the car is found bottom up after such an accident, which gives the impression that the car really had turned a complete somersault over the front axle. But it is an impossibility for a car to turn a front somersault. The restoring moment due to the weight of the car will, in every case, greatly exceed the overturning moment. It has been determined that the distance from the front axle to the position of the center of gravity, measured horizontally, would have to be less than the height of the center of gravity of the car above the ground, before somersaulting over the front axle would be possible. When this fact is taken into consideration, together with the available data, it readily becomes apparent that the difference between the two dimensions mentioned will be, even in extreme cases, of the order of 2 to 1, or more.

To visualize what actually takes place in such an accident, let us assume that a car has the braking force equally distributed between the two sets of wheels, front and rear, and is traveling at a speed of about 40 m.p.h. Let us then consider what happens when the brakes are suddenly jammed on for an emergency stop. Owing to the magnitude of the retarding force on a dry road, the change of effective weight will be very considerable, increasing the effective weight on the front wheels and decreasing the effective weight on the rear wheels, thus diminishing the friction between the road and the rear wheels. Consequently, the rear wheels will lock very easily; that is, the rear wheels will lose their sense of direction and will move in whatever direction the forces acting upon them may cause them to move, while the front wheels, on which the downward force has been increased, will continue to roll. Hence, they will not lose their sense of direction but will pursue any direction in which they are pointed.

In such an emergency stop on a dry road, two principal forces are trying to influence the direction of the car during the period of braking; namely, a centrifugal force and a large retarding force, the preponderance of which is at the front of the car, causing the spin effect to exceed the drag-anchor effect very considerably. Here

then is the condition that has been described previously in which the rear wheels are locked and the front wheels are rolling. A spin effect of great magnitude is superimposed on the centrifugal force and an exceedingly violent pivot follows.

The difference between the dry-roadway pivot and the skiddy-roadway pivot is merely that, when the axis of the car assumes the position of the line *ab*, as shown in Fig. 1, it is likely to overturn due to the great friction between the tires and the dry road; while, on a slippery road, the car is able to slide sidewise without overturning. The fact that after a dry-roadway pivot the car is found, in some instances, with the rear end pointing forward in the direction of car travel, may be due to the rotary energy accumulated during the pivot movement, which causes the car to spin in a horizontal plane during, or after, the period in which the car turned about its longitudinal axis.

Means of Eliminating Dry-Roadway Pivot

In thus analyzing the dry-roadway pivot it is seen that the accident can only be caused by a combination of two conditions; namely, that a stopping force of greater magnitude must be applied to the front wheels than to the rear wheels, concurrent with a locking of the rear wheels. It is apparent, then, that the dry-roadway pivot can be eliminated by making the forces just discussed non-concurrent. Three means of accomplishing this result are outlined, as follows:

(1) By eliminating the retarding forces on the front wheels; that is, by braking on the rear wheels only

(2) By eliminating all danger of locking the rear wheels; that is, by braking on the front wheels only

(3) By decreasing the retarding forces on the front wheels below the danger point; that is, when using four-wheel brakes, the preponderance of the entire decelerating force should be active behind the center of gravity of the car, so that the drag-anchor effect exceeds the spin effect

In the following summary of the relative merits of the three foregoing methods, it must be remembered that I am concerned with dry-roadway conditions only.

(1) With rear-wheel brakes only, braking is fairly satisfactory, although, in some instances, it might be desirable to bring a car to a more rapid stop than can thus be accomplished

(2) From the viewpoint of pivoting, nothing can be said against braking on the front wheels only. However, this method has some disadvantages, with which this paper has nothing to do

(3) By decreasing the retarding forces on the front wheels below the danger point, the principal advantages of braking on the rear wheels only are retained, with the additional advantage of increased stopping ability

Summary

It has been stated that because a car, the wheels of which are revolving, is never traveling continuously for any appreciable length of time in a mathematically straight course, the car is always under the influence of a transverse force. As long as the wheels are revolving, they possess a sense of direction which resists the transverse force and enables the car to be steered. But when a set of wheels lock, the wheels instantaneously cease to function as such and the car is to all intents and purposes mounted on rubber-covered skids that will move in whatever direction the forces acting upon them may cause them to move. Consequently it is undesirable to lock any set of wheels under any condition.

By analyzing the motion of a car on which a set of wheels is locked, it has been shown that the continuous rotation of the rear wheels is just as important, if not more so, to the steering ability of the car, as is the continuous rotation of the front wheels. Consequently, there is no cause to fear locking the front wheels in preference to locking the rear wheels. It has also been shown that the retarding forces at the front wheels cause a spin effect; that is, a force which does not influence the motion of the car as long as the rear wheels are revolving. Consequently, from the viewpoint of pivoting, the use of front-wheel brakes only is not in the least dangerous; but the use of front-wheel brakes simultaneously with rear-wheel brakes is a dangerous combination of braking equipment, if the front and the rear braking-forces are not combined in the correct proportion.

When discussing the distribution of the braking forces, two objectives must be kept in mind. It is not only necessary to design a system of four-wheel braking which is acting in a smooth and yet effective manner, but it is also essential to provide a system that is safe to use in an emergency stop; that is, when the average driver involuntarily will step with all his force on both the clutch and the brake-pedal. To simplify this problem it is necessary to treat "dry" and "skiddy" driving conditions separately.

The total amount of friction available between the road and the tires is comparatively great on a dry roadway. When using four-wheel brakes, the problem is therefore not to provide sufficient decelerating force to stop the car but is, on the contrary, to design a distribution of the braking force to the front-wheel and to the rear-wheel brakes that, in spite of the change of effective weight and the fact that the driver may press with all his force on the foot-pedal, will prevent the driver from making the too violent stop of the car which will cause a dry-roadway pivot, the most unexpected and dangerous of all accidents. When two-thirds of the braking force is distributed to the *rear wheels*, the preponderance of the stopping or braking force will remain active to the rear of the center of gravity of the car, causing the drag-anchor effect to counterbalance the spin effect, and no dry-roadway pivot can occur.

The friction available between the road and the tires is comparatively small on a skiddy roadway. The retarding forces available at the two sets of wheels, front and rear, should, therefore, be utilized to their utmost; that is, the force from the foot-pedal should be diverted to the set of front wheels and the set of rear wheels in accordance with their respective car-deceleration abilities, so that there will be the least possible chance of locking any of the wheels during the period of braking. Owing to the change of effective weight from the rear wheels to the front wheels, the brakes of the front wheels will resist much greater pressure from the foot-pedal before the wheels lock than will the brakes of the rear wheels before the rear wheels lock. Consequently, a greater braking-force should be distributed to the front wheels than is supplied to the rear wheels.

It has also been shown that the pivoting forces build up to the maximum when the braking force at the front wheels is of an amount just insufficient to cause them to lock when the rear wheels are locked. But if the front wheels are locked momentarily before the rear wheels lock, all pivoting forces become instantaneously eliminated and the car will pursue a more nearly straight ahead

course than would be possible for any driver to steer it. In addition to this absence of pivoting tendency, steering can always be regained at any instant by releasing the brakes, which is in striking contrast to the inability of regaining control over the car under any other condition caused by locking the wheels. If two-thirds of the braking force from the foot-pedal is distributed to the *front wheels* for skiddy-roadway conditions, the front wheels always will lock momentarily before the rear wheels lock, and no pivoting can occur.

It must, therefore, be concluded that the two conditions under which a car is brought to a stop, that is, on a skiddy roadway and on a dry roadway, are so different that it is necessary to design a four-wheel-brake system which combines two different methods of appropriate distribution of the braking force.

SYNTHETIC GASOLINE

THE various processes for converting coal into oil are too numerous to mention individually but, as they can be classified into two groups, the principles involved in these two fundamental methods can be described briefly. The scientists abroad have worked along the lines of as nearly complete conversion of the coal into oil as possible with no thought of using the fuel values in the coal in addition to the synthetic petroleum derivatives. To accomplish this end the coal is converted into a gas, similar to the water gas manufactured extensively for household and commercial use. By bringing hydrogen and carbon monoxide, constituents of water gas, in contact under pressure and high temperature in the presence of a catalyst, a product is obtained which is known abroad as Synthol, a combination of various products similar to certain alcohols and the lighter petroleum products. Synthol is suitable for use as a fuel oil and after a simple refining operation it yields a large portion of excellent motor fuel, similar in quality to the several brands of gasoline sold in the United States at a premium as anti-knock gasoline.

The importance of this process lies in the fact that no special kind of fuel is required. Any kind of coal or, in fact, coal dust, coke dust, wood waste, or any carbonaceous product that can be used to produce water gas is suitable. Through a recent improvement of the Bergius process, which itself is one of the most efficient truly synthetic processes, an authentic laboratory report showed a derivative of 45 per cent in benzene and lubricants, 6 per cent in combustible solids and 30 per cent in waste and gases permitted to escape, with only 15 per cent of ash. The fuel used in this instance was a semi-coke remaining after gases and tar had been extracted from a German soft coal through low-temperature carbonization, the principles of which will be described below as the second important method of extracting motor fuel from coal.

In the low-temperature carbonization process, the petroleum products are obtained as a by-product without destroying the fuel value of the coal treated. Commercially this process has more importance than the production of Synthol because large users of coal for steam-raising purposes can install the necessary equipment and produce petroleum products as a by-product without the necessity of obtaining a high price for the gasoline or lubricants obtained. The Synthol process, on the other hand, is only feasible wherever and whenever gasoline sells at a price to warrant the treatment of the coal. So far, this cost is calculated to be not much less, if any, than the cost of getting petroleum out of the ground.

At the present time, one of the operating subsidiaries of one of the largest public utility companies in this Country is using a semi-commercial unit installed for the production of synthetic petroleum products as a by-product in connection with its use of coal in the manufacture of electric current. Pulverized coal is fed into a vertical retort where it is distilled by heat, giving off a substance called "primary tar" which is treated in much the same way as crude oil to obtain synthetic gasoline, lubricants and heavier products. Thirty gallons is said to be obtained from 1 ton of coal which in turn can be treated to reproduce about 10 gal. of motor fuel and 10 gal. of lubricants. The residual coal after such treatment is a semi-smokeless fuel, still in pulverized form which is fed directly into the steam-raising boilers and is thus transformed into electrical energy.

The coal used in this process is a low-cost bituminous, bituminous is the only coal suitable for low-temperature carbonization, and the price differential between anthracite coal offsets both the loss in fuel value and the cost of treatment, both of which are nominal. In a sense, therefore, this particular company is able to obtain synthetic petroleum products for its own use or sale which cost it nothing. If inroads are to be made in the market for natural petroleum products, they will come from this direction. Numerous processes of a similar nature are still in or just emerging from the experimental stage both in foreign countries and the United States. A unique feature of the particular installation described is the fact that carbonization is completed in less than 35 sec. as compared with a period of from 2 to 20 hr. in the case of other processes. Continuous operation is thus possible on a large scale suitable to the requirements of the largest coal users in the United States.

Little imagination is required to grasp the possibilities of synthetic motor-fuel production from this or any similar process. The Brooklyn Manhattan Transit Corporation, for instance, uses about 2000 tons of coal per day. Calculate how much synthetic gasoline or lubricating oil it could produce a year at 10 gal. of each product for each ton of coal used, and if sold as a by-product how far it would go to reduce the company's coal bill or increase gross revenues. Obviously, public utilities cannot be expected to rush into the synthetic gasoline business without certain data relative to costs, mechanical operation on a commercial basis and other facts not obtainable at present. The intent of this discussion is merely to point to developments that over a period of years may exert a stabilizing influence on the market value of gasoline and other oil products.

Synthetic gasoline is not produced in sufficient quantities to send to market in this Country and years probably will elapse before it is manufactured in quantity that will materially influence prices.—W. T. Taylor in *Magazine of Wall Street*.

Inspection Along the Line

By A. H. FRAUENTHAL[1]

PRODUCTION MEETING PAPER

THE discussion following the presentation of this paper at the Production Meeting in Chicago last September was entirely verbal and was constituted of remarks made by those present from the floor or questions that were submitted on question cards which were read by the chairman and answered by the author. An opportunity was afforded the author to submit written replies to the points made in the discussion of the paper and an edited transcript of their remarks was sent to the various discussers for approval before publication.

For the convenience of the members a brief abstract of the paper precedes the discussion so that those who desire to gather some knowledge of the subjects covered without referring to the complete text as originally printed in the October, 1926, issue of THE JOURNAL, can do so with the minimum effort.

ABSTRACT

ALTHOUGH production has been increased greatly during the last decade by the use of special automatic machinery, conveyors and improved methods, plans for the application of wage incentives to indirect labor have not been widely adopted. Inasmuch as time-studies and some sort of wage-incentive system have served to keep the individual output of direct labor close to its assignment, the assumption is made that the labor of the indirect workers might also be so measured to a standard that the compensation would be governed by the quantity and the quality of the ultimate output.

The advantages and functions of inspection are discussed and a method is suggested for establishing a quality-bonus incentive-plan based on the amount of rejected and scrap material per car and the number of inspectors employed per unit of production. The manner of determining the number of inspectors in use at many plants is explained and the conclusion is reached that this number should be decided after a very thorough study of each department on the basis of scientific job-analysis.

Cam-rollers are cited as an illustration and a detailed description is given of the various inspection operations required in producing this unit. Reasons for the superiority of the direct-reading to the plug-gage method of inspection are given and comparative time-studies are reproduced in chart form.

Justification for time-studies is said to be found in the facts that (*a*) each inspector knows that a certain amount of work is expected of him; (*b*) the foreman can check the inspector's output rapidly and economically; (*c*) the chief inspector can check the output of a department over any given period with very little trouble; (*d*) the attention of everyone concerned is drawn to the possibility of economizing by better methods, mainly by impressing upon him the extreme slowness of some operations; and (*e*) a time-study is of assistance in planning the work, for the length of time necessary to keep an inspector on a job is known beforehand.

Flexibility is said to be an essential of an inspection system, and the most economical method, particularly with regard to material purchased outside, to be based partly on the importance of the various dimensions and partly on the general accuracy of each dimension as produced by the vendor.

In production-line inspection, a method of allotting a fairly definite time-interval for a given inspection is to adapt the inspection to a station in the line with a definite inspection-specification balanced in time with the production operations. This method applies particularly to Brinell testing large castings, such as cylinder-blocks and crankcases in the rough. When an inspection station is placed at the end of a line, the effect is to eliminate some of the machine inspection as well as to speed up the final inspection.

THE DISCUSSION

CHAIRMAN JOHN YOUNGER[2]:—It is interesting to note that in many shops the inspector is still considered a non-productive mechanic. An illustration is in the case of two shops, in one of which five ordinary lathes operated by five workmen turn out a certain quantity of product per hour. One inspector will be needed, let us say, for these five lathe operators. If the lathe jobs were produced in an automatic screw-machine only one operator would be needed for the same quantity of product. In one case, one inspector for five men would seem to be a very small non-productive inspection account. In the other case, you would have one inspector per man; yet in each case the inspector would be doing the same amount of work. That is one of the things that are not always obvious. Percentage, as Mr. Frauenthal says, is a very wrong figure to employ.

Another thing in which I am interested is the use of dial gages. Generally speaking, the dial gage is beginning to replace plug and ring gages. One of the latest ideas is to replace the 0.0001-in. increments on the dial gage with "go" and "no go" readings. That has one advantage in that less skilled inspectors can be used.

Does Mr. Frauenthal's plan of paying inspectors in accordance with the amount of work done require a more or less skilled inspector? In other words, what quality of inspector can be employed? Is the tendency for the skill required to increase or decrease?

A. H. FRAUENTHAL:—The tendency to use unskilled inspectors increases with the use of more automatic gaging-devices. A gaging-device of the type we use on cam-rollers has graduations on the dial indicator, but a small attachment on the dial has two fingers, one showing the "go" and the other the "no go" limit. The graduations are there to show how much over or under size the part is. We also use the graduations to classify the parts according to size. Any schoolboy or schoolgirl of the age of 12 can inspect cam-rollers for size and roundness of bore within the limits of accuracy of the machine, and either of them will do it as well as an experienced inspector. The chances are that they will do it a little better because they will be more interested in the job. We have found in our experience that it is necessary to make gages as fool-proof as possible. In designing, we have found it valuable to assume that a moron will operate each gage and cannot be allowed to use any judgment whatever. This is because many alibis are used by inspectors, most of which are pointed at the gages, and

[1] Jun. S.A.E.—Chief inspector, Chandler Motor Car Co., Cleveland.

[2] M.S.A.E.—Editor and publisher, *Automotive Abstracts;* professor, industrial engineering department, Ohio State University, Columbus, Ohio.

they are all produced as soon as anything goes wrong. We find that, when gages reach the point of development where they give absolutely no trouble in service, all the points demanding use of judgment have been eliminated and they are so simple that a child can use them. Gages of this type seem to be ideal but even they cause trouble occasionally, because they are so simple that the inspector's mind wanders and he does not pay much attention to the work. So long as he goes through the motions he is content. Very inexperienced help with very poorly trained minds can be used advantageously to perform some of the more automatic operations.

B. H. GILPIN[3]:—Is Mr. Frauenthal's experience more or less the same as ours with respect to trying to apply definite time-limits to operators who are changed from one job to another by the production department? We have certain operators in our plant who perform an operation probably 99 per cent accurately. When an operation varies beyond the tolerance the parts are laid aside and the inspector is called. In other words, we do not have to inspect the parts turned out by that operator except to go over them occasionally to see that he is going right. If the production department changes that operator and puts on a more careless man, we inspect his work almost 100 per cent.

How would you apply time-study to incentive payment when you have such conditions to contend with? We have them more or less throughout our whole shop. Sometimes it is not entirely the operator's fault. We have some operators who are accurate but they will not stop the machine when it begins to vary a little from the tolerance set. When it is 0.0005 in. out, they take a chance on arguing and keeping the machine going.

MR. FRAUENTHAL:—That subject was partly considered under another head, namely, buying material from outside vendors. If material is purchased from one vendor, it may have to be inspected 100 per cent in every operation. If the purchasing department should buy the next lot from another vendor, it might not have to be inspected 100 per cent on any operation.

Regarding the changing of an operator, just picture the time-study of the cam-roller job, for instance, in which there are four different major finishing production operations and six different inspection operations. If an experienced man is grinding the cam-rollers to size, we do not have to inspect them. The reason we do not have to inspect them is not that an experienced man is there, but that they have been found to be running practically perfect. Then we decide that we will not inspect that operation 100 per cent. The next time, the cam-roller may be perfect with the exception that the side faces have been ground poorly, so we inspect that operation 100 per cent and have a time-study for it. It does not mean that the route-sheet must be followed exactly but a time-study is available for use on any or all operations.

EUGENE BOUTON[4]:—We have been putting indirect labor on the percentage basis for some time; we are working on the inspection division and some of it looks very feasible. Many subforemen, truckers and sweepers have been included in the direct-labor group prices and the plan has worked out very successfully. Part of the indirect labor has been included in the direct-labor cost. Production men generally agree that indirect labor should be rewarded for extra effort in the same manner as direct labor. I think the time is coming when we shall find a greater percentage applied to indirect labor.

P. W. RHAME[5]:—Two points have been mentioned. One is when to put on 100-per cent inspection; the other relates to the operator, who tries to argue and continues to run the machine when the parts are not within the limits of a new unworn gage. We have a fixed understanding on percentage inspection in all our work. If our operation sheets call for 1-per cent inspection, we check parts on a 1-per cent basis. If the pan carries 2000 parts, 20 pieces are checked. As a result, if 2 per cent of the 1 per cent is beyond the limits, the fact automatically comes to the foreman's attention. The foreman then decides whether to revert to 100-per cent inspection on everything or let the rejections go through. That answers the question of what to do and when to do it; and the rule applies to material that is purchased as well as to our own material.

The question of the inevitable wear of gages and the resulting crossing of limits is worked out by a dual limit policy; the machine man has a closer limit than the inspection-gage, and he is obliged to work to this gage. The final more liberal inspection-gage limit agrees with the blueprint. This has decreased rejections and eliminated many arguments.

MR. FRAUENTHAL:—The method of using two different tolerances, one for the man who is machining and another for the inspector, has been tried out. Some companies have tried it and have discontinued it; others seem to find that it works very well. I cannot imagine attempting to do that in our plant, that is, to furnish the machine division with gages that had slightly less tolerance than those called for by the drawing. I do not believe they would stand for it. I do not believe the production of the material would be as economical, if the tolerances were squeezed down. As a matter of fact, the standardized method of plug-gaging, as contained in the National plain-gage report and in the National screw-thread report, call for that type of gaging. I have always wondered whether it would be widely adopted. It seems to me that we ought to have limits. The limits ought to be properly set by the engineering department, so that the parts will function properly; and when they have been adopted, they should be adhered to. Dual limits must certainly form a basis for arguing and dickering.

E. A. TAYLOR[6]:—Is Mr. Frauenthal willing to tell us what is the average percentage of the cost of inspecting the general manufacturing items that go through the machine-shop?

MR. FRAUENTHAL:—Machine-shop inspection varies because our business varies. If a group of machines are running on separate operations during a busy season, we average about two operators to three machines. When business slackens and we have to lay off some of the men, one man may have to operate five machines. Of course, he will not run them all at once, but he must run five separate machines at different times. A man working on 1½ machines becomes very skilled in those operations. When another man first begins to run five machines, he is unskilled on the operations that have been added. The same thing also happens to a certain extent with the inspector, so it seems that when the operating force in the machine department is cut down, the force in the inspection department should be increased, because more and harder inspection work must be done. Inspectors

[3] M.S.A.E.—Quality manager, H. H. Franklin Mfg. Co., Syracuse, N. Y.

[4] M.S.A.E.—Superintendent of time study, Chandler Motor Car Co., Cleveland.

[5] A.S.A.E.—Superintendent of inspection, A. C. Spark Plug Co., Flint, Mich.

[6] M.S.A.E.—Works manager, Yellow Sleeve Valve Engine Works, Inc., East Moline, Ill.

must be more careful and cannot get around so quickly. It is difficult to convince the management of this fact but that is what ought to be done. When the machine-shop is operating with a full force, there is 1 inspector to about every 11½ operators. That does not cover the entire inspection, but is merely the machine-shop line-inspection. Some work must be inspected 100 per cent after that.

MR. BOUTON:—We frequently read about and hear from various sources of the number of inspectors required for productive workers. The number runs from 5 to 25. Some men express the opinion that this ratio is about right. I never could find out why it is so. I heard a prominent production man in Detroit make the statement that he did not care whether it took five truckers to keep one machine going or five inspectors to check one man, if it were economy to do it, he would do it; that ratios and percentages were meaningless.

MR. GILPIN:—I have made a careful study of that subject during the last few years. When you speak of inspectors, what do you mean? Do you mean machine-shop inspectors or quality-control inspectors? In our shops, we operate entirely and use the term "quality control." We do not use the term "inspection" as much as "quality control"; and for our information and as a basis on which we work up our budgets to control the cost of quality control, we include the chemical and physical laboratories, road testing, vendor inspection, receiving inspection, inspection at the body plants, and all the overhead expense and supervision that composes the entire organization. I have yet to find any other organization that includes nearly as much as we do, when it speaks of ratios of inspection. Again, some men base inspection entirely on direct-labor cost, and they term the direct-labor cost, the cost of manufacturing in their plants. One manufacturer makes about 85 per cent of his entire car, another 50 per cent, and some others a still smaller percentage. When you try to work out a basis of percentage and ratios, you do not get anywhere.

CHAIRMAN YOUNGER:—One ratio that I found a few days ago surprised me. The amount of time spent in actual fabrication of the automobile, the cutting of the metal or the assembling of parts is 10 per cent; and 90 per cent is spent in preparation and the non-cutting of the metal. Has Mr. Gilpin found any justification of that percentage?

MR. GILPIN:—I have never studied that particular angle very closely. But, comparing our factory again with some other factories that I have studied, it is very difficult to get the exact direct-labor time because one shop will have a regular machine set-up man who spends his entire time in setting up machines. The operator steps directly from one machine to another and loses no time at all. In other shops, the operator sets up his own machine and, in some places, that time is included in the direct-labor time; in other places, it is not.

It seems to me that in almost every factory, and sometimes in the same factory, different departments work differently, because of the difficulty of setting up some kinds of jobs and the simplicity of setting up others. In some places an operator can set up his machine as well as the foreman or a job-setter who is paid a higher price; consequently, in placing the job and paying a bonus, the set-up time, when the operator does the setting up, is included; sometimes, when a job-setter or some foreman does it, it is excluded. It is very difficult to draw comparisons and to know what they mean when ratios are figured.

FIRING ORDERS WRONG

IN the paper by H. M. Crane entitled Engine Characteristics as Affected by Cylinder and Crankcase Arrangement, which was printed in the December, 1926, issue of THE JOURNAL, the firing orders given in the caption to Fig. 21 on p. 590 were transposed. The illustration with the firing orders properly arranged is printed below.

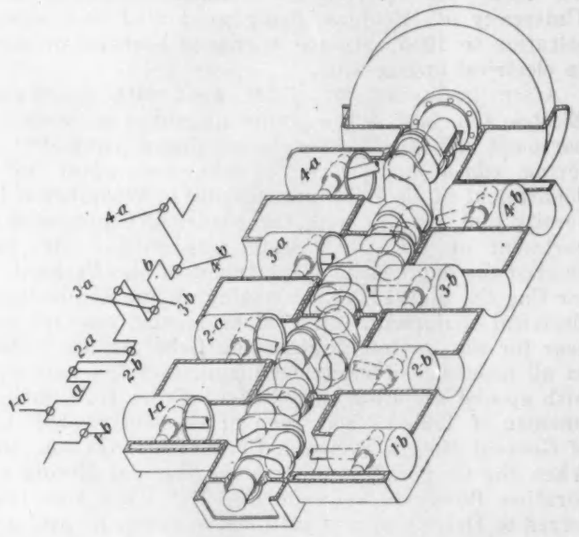


FIG. 21—COMPLETE VIEW OF THE EIGHT-CYLINDER-OPPOSED ENGINE, THE CRANKSHAFT OF WHICH IS ILLUSTRATED IN THE BOTTOM VIEW OF FIG. 20

The Engine Should Be in Nearly Perfect Running Balance. The Local Pressures All Along the Shaft Are About as Slight as Can Be Expected in an Engine Having Eight Cylinders, and the Engine Would Be as Short as a Six-Cylinder Engine Having the Same Displacement. At the Left Is Shown a Sketch of a Possible Arrangement of the Crankshaft in Which the Dynamic Pressures on the *a* and *b* Bearings Are 40-Per Cent Greater Than Those on the Same Bearings of the Engine Illustrated in the Other Drawing. The Firing-Order of the Engine in the Smaller Drawing Is

Order of Cylinders			
0 and 360 Deg.	90 and 450 Deg.	180 and 540 Deg.	270 and 630 Deg.
1*a* and 1*b*	2*a* and 2*b*	3*a* and 3*b*	4*a* and 4*b*

1*a*-3*b*-2*b*-4*a*-1*b*-3*a*-2*a*-4*b*
1*a*-3*b*-2*a*-4*b*-1*b*-3*a*-2*b*-4*a*
1*a*-3*a*-2*a*-4*a*-1*b*-3*b*-2*b*-4*b*

The Firing-Order of the Engine in the Larger Drawing Is

Order of Cylinders			
0 and 360 Deg.	90 and 450 Deg.	180 and 540 Deg.	270 and 630 Deg.
1*a* and 1*b*	2*a* and 2*b*	3*a* and 3*b*	4*a* and 4*b*

1*a*-2*b*-3*a*-4*b*-1*b*-2*a*-3*b*-4*a*
1*a*-2*a*-3*a*-4*a*-1*b*-2*b*-3*b*-4*b*
1*a*-2*a*-3*b*-4*b*-1*b*-2*b*-3*a*-4*a*

Officers of the Society

At the Annual Meeting of the Society held last month a President, a First Vice-President, five Second Vice-Presidents representing motor-car, tractor, aviation, marine and stationary internal-combustion engineering respectively, and three Councilors were elected and the Treasurer was reelected. In addition to these officers the three Councilors who were elected at the 1926 Annual Meeting and the last Past-President are voting members of the Council for 1927. In accordance with the usual custom photographs of the members of the Council are presented on the following pages.

J. H. Hunt

President Hunt was born at Saranac, Mich., on March 24, 1882. He received his technical education at the University of Michigan, being graduated from that institution in 1905 with the degree of bachelor of science in electrical engineering.

After graduation Mr. Hunt went with the Western Electric Co., first in the power apparatus apprentice department and later in the engineering department. Entering educational work, 1 year was spent in the department of electrical engineering at Washington University and 5 years with the electrical engineering department at the Ohio State University. Mr. Hunt entered the engineering department of the Packard Motor Car Co. in 1912, concentrating on the application of electrical equipment. In 1913 he became research engineer for the Dayton Engineering Laboratories, working on all problems of electrical installations on motor-cars with special attention to ignition. From 1920 until the summer of 1925 he was head of the electrical division of General Motors Research Corporation, Dayton, Ohio. When the Corporation became the General Motors Corporation Research Laboratories, Mr. Hunt was transferred to Detroit where, until last summer, he held a position similar to that which he held at Dayton. At that time he was assigned to special work for the Chevrolet Motor Co.

Mr. Hunt was elected to Member Grade in the Society on Jan. 14, 1916. He was active in the Dayton Section from its organization, until his transfer to Detroit, serving as Chairman for the administrative year of 1922. For the last 3 years he has been Chairman of the Sections Committee and also Vice-Chairman of the Lighting Division of the Standards Committee. Last year Mr. Hunt was a member of the Research Committee and also First Vice-President of the Society.

Heavy-Fuel Carbureter-Type Engine was the subject of a paper presented by Mr. Hunt in 1919 at a meeting of the Metropolitan Section. In 1920 he described Battery-Ignition Systems before the Cleveland Section, and Science and Engineering was his topic at a meeting of the Indiana Section. In collaboration with G. F. Embshoff, also of the General Motors Research Corporation, a paper on Some New Electrical Instruments for Automotive Research was presented before the Cleveland and the Indiana Sections in the spring of 1925. Mr. Hunt also contributed to the symposia on Automobile Headlighting at the May, 1925, meeting of the Metropolitan Section and the 1926 Annual and Semi-Annual Meetings.

William Guy Wall

First Vice-President Wall was born on Aug. 7, 1875, at Baltimore. He was graduated in civil engineering at the Virginia Military Institute in 1894 and then attended the Massachusetts Institute of Technology, receiving the degree of bachelor of science in electrical and mechanical engineering in 1896. He then entered the service of the southern agency of the General Electric Co. at Charlotte, N. C. Leaving there in 1898 he practised electrical engineering in Richmond, Va. While there he installed some large steam and electric powerplants, did consulting engineering work for the William R. Trigg Shipbuilding Co. and assisted in changing from steam to internal-combustion engines the powerplant equipment of the first American submarine, the Plunger.

Mr. Wall built a gasoline automobile at Richmond, Va., in 1898 and 1899, probably the first one in the South, and has been engaged in the design and construction of motor-cars ever since. In 1900 he became associated with the newly organized National Motor Vehicle Co., Indianapolis, as mechanical engineer and designer, and later became chief engineer and vice-president of that company. While chief engineer he put the first six-cylinder car on the American market and designed all the National racing cars, including the winner of the 1912 Indianapolis Speedway Race. At the present time he is a consulting engineer in Indianapolis, Colonel in the United States Reserve Corps, and Chairman of the Army Ordnance Advisory Board.

In May, 1917, Mr. Wall entered the Army as a Major in the Engineering Division of the Ordnance Department, being promoted to a Lieutenant-Colonelcy in the following year. In January, 1918, he was sent overseas, at first with the American forces and later was transferred to the First British Army and from there to the Sixth French Army. He was in the battles of the Somme Defensive, Leys and the Aisne and was recommended for distinguished service medal. As a result of his work on the possible improvement in the motorization of big guns, he was made Chief of the Motor Equipment Section of the Ordnance Department, on his return to the United States, and until he was mustered out of the service in the spring of 1919 was engaged in designing tractor caissons and installing heavy guns on caterpillar self-propelled mounts. An outline of the work which he accomplished in this post, was given in the paper that he presented at the 1919 Annual Meeting of the Society. In addition to the paper on Automotive Ordnance Apparatus one on Details and Peculiarities of Design of Foreign Cars, was printed in Part I of the Transactions for 1912 and Mr. Wall contributed to the Oil-Rectifying Devices Symposium at the February, 1926, meeting of the Indiana Section.

Mr. Wall was elected to membership in the Society in 1906. He served as a Vice-President from 1913 to 1915 and was elected Second Vice-President representing motor-car engineering at the 1920 Annual Meeting. He was a member of the Constitution Committee in 1920. In 1922 Mr. Wall was Vice-Chairman of the Standards Committee and a member of the Storage-Battery Division, and served on the Passenger-Car Division the following year.

Fred M. Zeder

Second Vice-President Zeder, representing motor-car engineering, was born in Bay City, Mich., on March 19, 1886, and attended the grade and high schools of his

J. H. HUNT

birthplace. During vacations and following his graduation from high school, Mr. Zeder worked as a machinist apprentice in the Industrial Works of Bay City. After finishing his apprenticeship he accepted a position with the Michigan Central Railroad in the motive power and train divisions and after working there for a short time he entered the University of Michigan in 1905. At the University, Mr. Zeder studied mechanical, electrical and chemical subjects and was graduated in 1909 with the degree of bachelor of science in mechanical engineering.

Immediately after graduating from college he enrolled in the apprenticeship course of the Allis-Chalmers Co., of Milwaukee, and in 1910 was appointed its erecting engineer. The following year he became associated with the E. M. F. Co. where he had charge of the laboratories. He remained with this organization 2 years, during which time he was also engaged in the practice of consulting engineering and in powerplant work. In 1913 Mr. Zeder was appointed consulting engineer for the Studebaker Corporation and in 1915 was promoted to chief engineer, a position that he held until 1920 when he became associated with Walter P. Chrysler who was at that time executive vice-president of the John N. Willys interests. Mr. Zeder formed the consulting engineering firm of Zeder-Skelton-Breer Engineering Co., at Newark, N. J., in 1921 and was elected president. When the Chrysler Corporation was first formed in 1923 he was appointed vice-president in charge of engineering, his present position.

Mr. Zeder was elected to Member grade in the Society on Sept. 25, 1920. He is also a member of the American Society of Mechanical Engineers and the American Society for Testing Materials.

J. F. Max Patitz

Second Vice-President Patitz representing tractor engineering was born at Muegln, Saxony, Germany, on May 21, 1866. He completed a course in the Royal High School at Dresden and emigrated to the United States in 1881.

The first 4 years that Mr. Patitz spent in the United States were in factories and machine-shops in Pittsburgh and vicinity. In June, 1885, he entered the service of the E. P. Allis Co. at Milwaukee, eventually becoming one of its designing engineers. When this company was absorbed by the Allis-Chalmers Co. in 1900, he was first in charge of the building of steam engines and air-compressors and during this time designed many improved features that are now found on steam and compressed-air machinery. In 1902 and 1903 Mr. Patitz paid an extended visit to Europe where he made a thorough investigation of the design and operation of steam turbines and gas engines. A second trip to Europe was made in 1913, at which time he studied the new types of soil-tilling machinery in use in France and Germany. When the Allis-Chalmers Co. entered the tractor field the following year, Mr. Patitz paid especial attention to this phase of the company's activities since he had been interested in the development of machinery for cultivation since 1911. Mr. Patitz now holds the position of chief consulting-engineer with the Allis-Chalmers Mfg. Co.

Mr. Patitz was elected to Member grade in the Society on March 14, 1917. This is the second time that he has served as Second Vice-President representing tractor engineering, his first term having been in 1924. Mr. Patitz was a member of the Agricultural Power Equipment Division of the Standards Committee in 1923 and was Chairman of that Division for 1924 and 1926. In 1891 Mr. Patitz was elected a Junior member of the American Society of Mechanical Engineers and became a member of that Society in 1900. He is also a member of the American Society of Agricultural Engineers.

Edward T. Jones

Second Vice-President Jones representing aviation engineering was born at Saratoga Springs, N. Y., on Oct. 20, 1888. His technical education was obtained at Cornell University and he was graduated from there in 1911 with the degree of mechanical engineer.

After graduation Mr. Jones took the apprentice course with the Westinghouse Electric & Mfg. Co., East Pittsburgh and in 1912 accepted a position as instructor in engineering thermodynamics at Cornell University. In 1915 he went with the H. H. Franklin Mfg. Co., Syracuse, N. Y., as experimental engineer and left there in 1916 to act as inspector of airplanes and aeronautic engines for the Signal Corps. In 1917 he was commissioned as First Lieutenant in the Air Service and after 18 months of aircraft production work was transferred to the powerplant section of the engineering division, becoming chief of that section in 1922. On Dec. 15, 1925, Mr. Jones became chief of the engine design department of the Wright Aeronautical Corporation at Paterson, N. J., his present position.

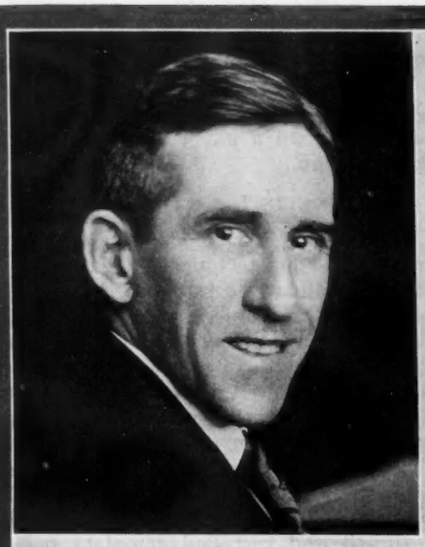
Mr. Jones was elected to Member grade in the Society on March 15, 1926, and was a member of Aeronautic Division of the Standards Committee last year. At the 1926 Aeronautic Meeting of the Society he presented a paper dealing with the development of the Wright Whirlwind Type J-5 Aircraft Engine.

Paul G. Zimmermann

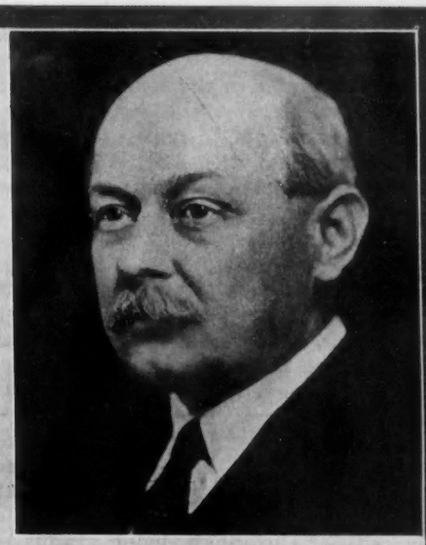
Second Vice-President Zimmermann representing marine engineering was born at Iroquois, S. D., on May 12, 1890. He received his education in the elementary schools of his birthplace and Sioux Falls, S. D., and at the high school in San Juan, P. R. In 1904, Mr. Zimmermann entered the service of Swift & Co. at San Juan as salesman, a position that he held for 5 years. Returning to the United States in 1909, he entered Rensselaer Polytechnic Institute, Troy, N. Y.

Following his graduation in 1913 with the degree of mechanical engineer, he became associated with the Knox Automobile Co., Springfield, Mass., remaining there until November, 1914. While with that Company Mr. Zimmermann was a student in the shops and a salesman and a branch manager at Rochester, N. Y. His next connection was with the Curtiss Aeroplane & Motor Co. at Buffalo and Hammondsport, N. Y., where he was successively chief draftsman and assistant chief aeronautical engineer. In November, 1917, Mr. Zimmermann resigned to accept the position of chief engineer with the Engle Aircraft Co., Niles, Ohio, remaining there until May, 1918. The next 5 months he spent exploiting a large airplane to be used in the war and in September, 1918, he accepted a position as chief aeronautical engineer with the Aeromarine Plane & Motor Co., Keyport, N. J. In 1924 he left the Aeromarine Company and engaged in business for himself at Keyport in the design and construction of metal fuselages. At present Mr. Zimmermann is vice-president in charge of manufacturing with the Sea Sled Corporation, West Mystic, Conn., a position that he has held since the early part of last year.

Mr. Zimmermann's work in the aeronautical industry includes the design of a number of Curtiss airplanes. He also designed the first cabin flying-boat used in this Country and converted and designed the passenger-cabin



E. T. JONES



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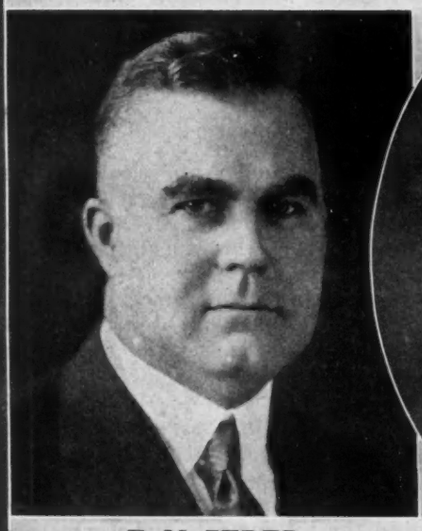
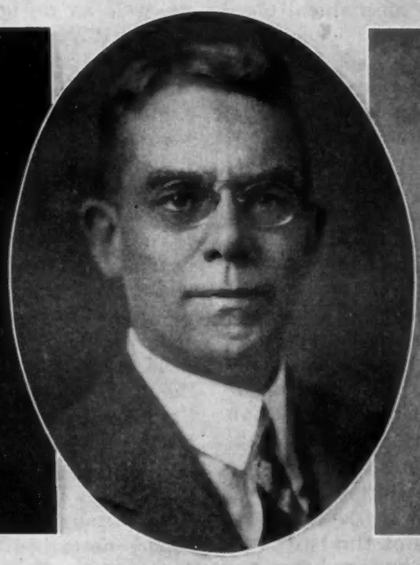
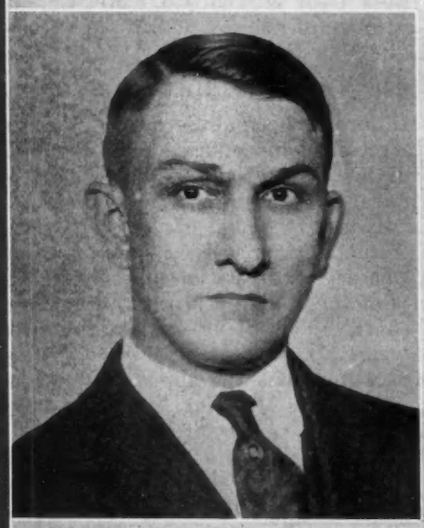


F. M. ZEDER

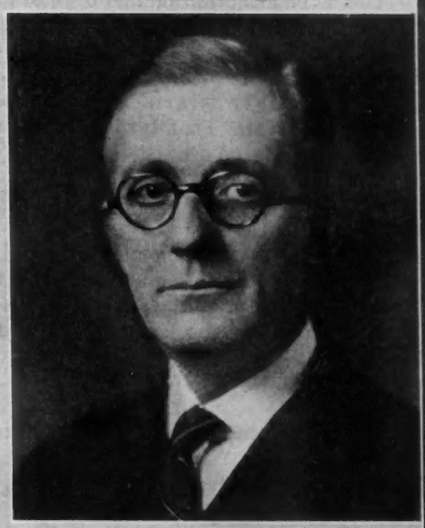


W. G. WALL

P. G. ZIMMERMANN



C. B. JAHNKE



T. J. LITLE, JR.

of the first flying-boat to be used for passenger service in this Country. The construction of the first two metal-hull flying-boats built in the United States is one of his achievements, as is also the construction of the first commercial flying-boats to make the trip between New York City and Porto Rico. Mr. Zimmermann designed the first variable-thickness wing to be used on American military airplane.

He was elected a Member of the Society on June 19, 1922. This is the second time that he has held office in the Society, his first having been in 1925 when he served as Second Vice-President representing aviation engineering. In 1925 Mr. Zimmermann was a member of the Aeronautic Division of the Standards Committee, and last year he served on the Motorboat Division.

Charles B. Jahnke

Second Vice-President Jahnke representing stationary internal-combustion engineering was born at Cincinnati on Jan. 4, 1889. He received his technical education at the University of Cincinnati, being graduated from that institution in 1910 with the degree of mechanical engineer.

Following his graduation Mr. Jahnke took the technical apprentice course with the Fairbanks-Morse Co., covering the erection and testing of the products of this organization. Upon completion of his course he was transferred to the experimental department as an experimental engineer, subsequently becoming superintendent. In 1919 he was appointed development engineer and was engaged in research work on oil engines. Subsequently Mr. Jahnke was made field engineer and in 1922 was appointed assistant chief engineer of the Fairbanks-Morse organization, being promoted to chief engineer in 1924. In July of the following year he was appointed works manager of the Beloit Works and held this position until Sept. 1, 1926, when he was appointed director of engineering in charge of engineering, general inspection of all manufactured products, installation engineering, field service, experimental work, and the laboratories of the Beloit, Sheffield and Indianapolis plants. Most of the work done by Mr. Jahnke has been in development of marine and stationary Diesel engines of the two-cycle solid-injection type although he has been engaged to some extent in the development of farm lighting plants and farm power machinery.

Mr. Jahnke was elected to Member grade in the Society on Jan. 8, 1925. He was a member of the Stationary Engine Division of the Standards Committee for 1925 and served on the Engine and the Isolated Electric Lighting Plant Divisions last year.

Charles B. Whittelsey

Treasurer Whittelsey was born at New Haven, Conn., on March 16, 1869. His education has been gained chiefly through practical contact with business.

His connection with the automotive industry dates from 1901, when he became associated with the Hartford Rubber Works Co. In 1911 Mr. Whittelsey became factory manager of the organization, and in 1916 he was elected to the presidency, which office he has held ever since.

Mr. Whittelsey was elected to Member grade in the Society in 1910, and to Life Member grade in 1916. He was appointed on the Standards Committee in 1911 and served for several years, being chairman of the Tire and Rim Division in 1918 and 1919. Mr. Whittelsey was a member of the Council in 1912 and 1913. In 1918 he was elected Treasurer of the Society, which office he has held continuously since that time. At present he is also a member of the Finance and Resignations Committees.

At the Annual Meeting in 1912, Mr. Whittelsey presented a paper on Solid Motor Tires and at the 1915 Annual Meeting he read a paper entitled the Pros and Cons of Tire Inflation.

Franklin F. Chandler

Councilor Chandler was born at Indianapolis on Dec. 27, 1876, and received his technical education at Purdue University, being graduated in 1899 with the degree of bachelor of science in mechanical engineering. After his graduation he taught machine design at that institution for 1 year.

The Chandler & Taylor Co., Indianapolis, was Mr. Chandler's first business connection. He became associated with this organization in May, 1900, and worked through several different departments, finally becoming manager of sales. While associated with the Chandler & Taylor Co., he was engaged in consulting engineering work and designed and installed complete powerplants as well as designing and building farm tractors. In April, 1923, Mr. Chandler went with the Ross Gear & Tool Co., Lafayette, Ind., as chief engineer, a position that he still holds. Since his association with the Ross Company, he has designed and built recording instruments for measuring the effort necessary to steer automobiles in motion.

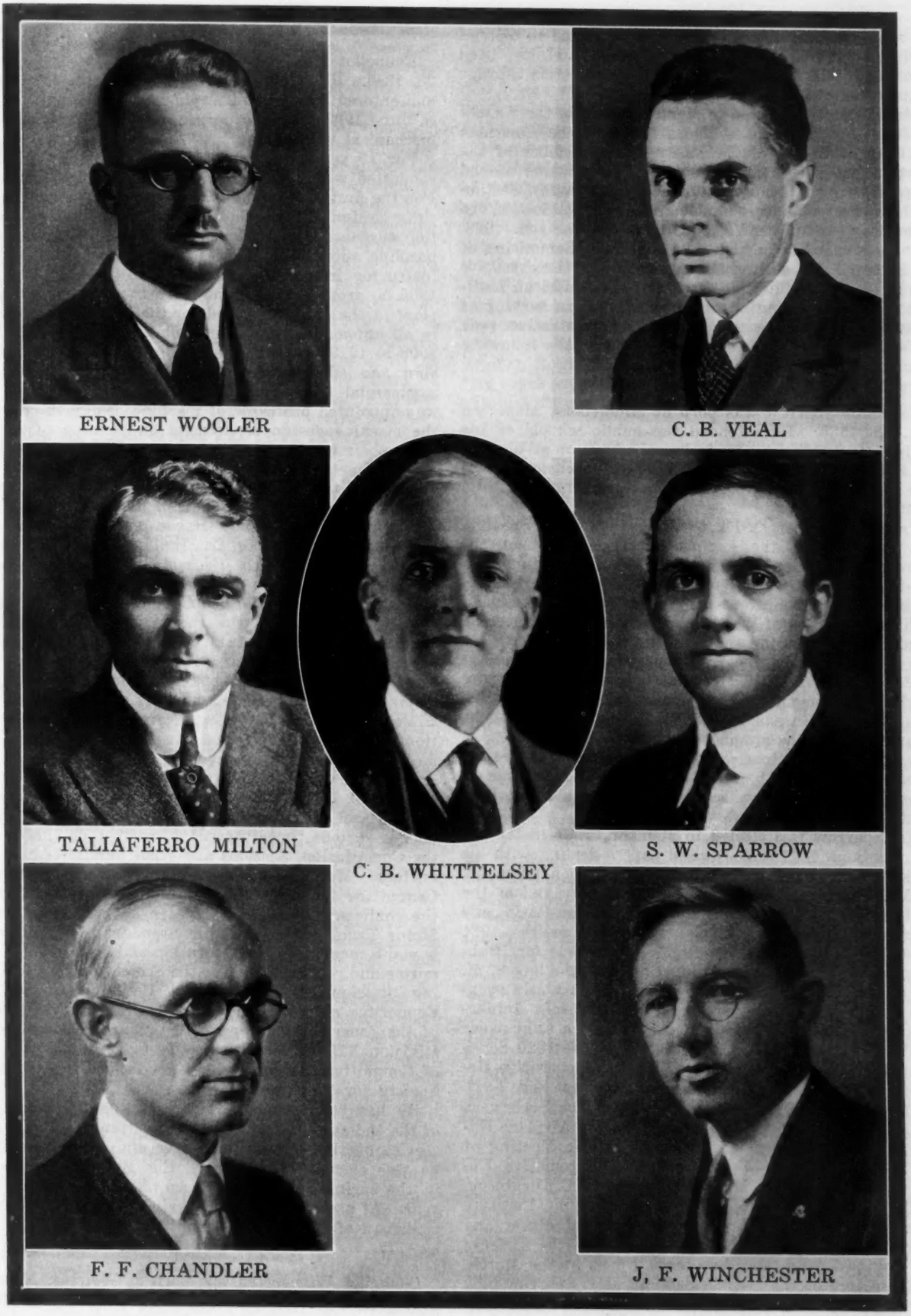
In July, 1916, Mr. Chandler was elected a member of the board of trustees of Purdue University and at present is chairman of the standing committee on technology and engineering, having held this appointment for several years.

Mr. Chandler was elected to Member grade in the Society on April 12, 1919. He has been prominent in the work of the Indiana Section, serving as Chairman for the administrative years 1923 and 1924 and as Vice-Chairman for 1925. At the April, 1924, meeting of the Indiana Section he read his paper entitled Steering-Gear Analyses and was the author of a paper entitled How Hard Does a Car Steer which he presented at the 1925 Annual Meeting of the Society. Both of these papers described the instruments and work that he had done at the Ross Gear & Tool Co. Mr. Chandler was appointed a member of the Sections Committee in 1924 and served as its Vice-Chairman in 1925.

Taliaferro Milton

Councilor Milton was born at Berryville, Va., on March 26, 1877. He received his education in the public and high schools of his birthplace and also at the Virginia Military Institute, Lexington, Va., receiving the degree of bachelor of science in 1900. He was commandant of the Sewanee, Tenn., Grammar School for the year 1897-1898, leaving to accept the position of assistant professor of mathematics at the Virginia Military Institute, where he remained until 1903, being assistant professor of physics for 4 years.

In 1903, Mr. Milton took the apprentice course at the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., and in 1905 entered the service of the New York Central & Hudson River Railroad in its engineering department where he was connected with the work on the New York City electrified zone. He accepted a position as sales engineer in the Chicago office of the Gould Storage Battery Co. in 1906 and the following year became associated with the Electric Storage Battery Co. as sales engineer in its Cleveland office. For the next 2 years he was attached to the San Francisco office of that company in



ERNEST WOOLER

C. B. VEAL

TALIAFERRO MILTON

C. B. WHITTELSEY

S. W. SPARROW

F. F. CHANDLER

J, F. WINCHESTER

the same capacity. In 1909 he was promoted to district engineer with headquarters at Chicago and has been manager of the Chicago branch of the Electric Storage Battery Co. since 1920.

Mr. Milton was elected to Member grade in the Society on June 23, 1913. He is also a fellow of the American Institute of Electrical Engineers and a member of the Western Society of Engineers. In 1921 he was elected Secretary of the Mid-West (now the Chicago) Section of the Society and served as Chairman of the Section the following year and as Vice-Chairman for the year 1923. He was a member of the 1924 Meetings Committee of the Society. Mr. Milton was a member of the executive committee of the Chicago Section of the American Institute of Electrical Engineers for several years, serving as Secretary of the Section for the administrative year 1915-1916 and as Chairman of the Section the following year.

S. W. Sparrow

Councilor Sparrow was born at Middleboro, Mass., on Nov. 18, 1888. He attended the public schools of his birthplace and received his technical education at Worcester Polytechnic Institute, the degree of bachelor of science in mechanical engineering being conferred upon him in 1911.

From September, 1911, to July, 1914, Mr. Sparrow was employed in the engineering department of the Stevens-Duryea Co., Chicopee Falls, Mass., and for about two-thirds of this time was engaged in experimental work. From the Stevens-Duryea organization he went with the Metz Co., of Waltham, Mass., in the engineering department, remaining there until 1917. The next year was spent in the engineering department of the Robert T. Pollock Co. In 1918 Mr. Sparrow entered the service of the Government, having charge of aviation engine testing at the Bureau of Standards until 1924 when he became head of the automotive powerplants section. On Nov. 1, 1926, Mr. Sparrow became a member of the engineering department of the Studebaker Corporation of America and he is now located at the South Bend, Ind., plant.

Mr. Sparrow was elected to Member grade in the Society on Sept. 10, 1917. Several papers dealing with his work at the Bureau of Standards have been presented by Mr. Sparrow at meetings of the Society and of the local sections. These include Compression-Ratio and Thermal Efficiency of Airplane Engines, at the 1921 Annual Meeting of the Society; Testing Fuels for High-Compression Engines, in conjunction with the late S. M. Lee at the 1923 Annual Meeting of the Society as a progress report on the Cooperative Fuel Research; Intake-Manifold Temperatures and Fuel Economy, a joint paper by W. S. James and H. C. Dickinson, at the 1920 Semi-Annual Meeting of the Society; Recent Cooperative Research Progress, presented by Mr. Sparrow and J. O. Eisinger at the 1925 Annual Meeting of the Society as a Fuel Research progress report; Flying an Airplane Engine on the Ground, at the 1920 Aeronautic Meeting of the Society; Possible Fuel Savings in Automotive Engines, a joint paper by Mr. Sparrow and H. C. Dickinson, at the meeting of the American Petroleum Institute which was held in November, 1920; Preignition and Spark-Plugs, at the 1920 Annual Meeting of the Society; and Engine Design and Antiknock Fuels, at the March, 1926, meeting of the Detroit Section. Mr. Sparrow took a prominent part in the affairs of the Washington Section of the Society, serving as Chairman for the year 1925-1926.

C. B. Veal

Councilor Veal was born at Greensfork, Ind., on Feb. 23, 1880. He received his education in the local schools and entered Purdue University in 1898, being graduated in June 1902 with the degree of bachelor of science in mechanical engineering.

For 15 years following his graduation Mr. Veal was connected with Purdue University in various capacities. For the first 2 years he was assistant instructor in machine design and taught the design of internal-combustion engines. He developed the course in the design of gasoline automobile engines in 1903 and 1904 and was instructor in machine design from 1904 to 1907. In 1905 he proposed and established the automobile testing plant at the University and for the next 4 years assisted in all automobile and automobile engine testing. From 1908 to 1910 he was assistant professor of machine design and administered the course in automobile and commercial truck design for the year 1910-1911. He was appointed professor of machine design in charge of the machine design department and testing of automobiles, their engines and parts, including the heat-treatment of metals, in 1911 and remained there until 1917.

While at the University Mr. Veal was engaged in consulting engineering work, some of his clients being W. H. McIntyre Co.; McCormick Harvester Co.; Western Electric Co.; Rockwood Mfg. Co., Indianapolis; Peru Heating Co., Peru, Ind., and the Central Station Steam Co., Detroit. From 1912 to 1917 he was the mechanical engineer for the Public Service Commission of Indiana and research engineer of the Indiana State Board of Accounts from 1915 to 1917. In 1916 Mr. Veal became associated with the Curtiss Aeroplane & Motor Corporation, Buffalo, as assistant chief inspecting engineer, leaving in 1920 to become a member of the firm of Manly & Veal, consulting engineers, New York City, a connection that he still continues. In September of last year he became Research Manager of the Society.

Mr. Veal was elected to Member grade in the Society on Feb. 10, 1912. He was an active member of the original Research Committee of the Society from its formation and at various times served as member or chairman of the Constitution, Sections and other administrative committees. Mr. Veal has been a member of the Grading Committee for several years and for the last 2 years, the chairman. For several years he has served on the Motor Truck Division of the Standards Committee and is now a member of the Operation and Maintenance Committee and representative of the Society on the Engineering division of the National Research Council, the Committee on Form and Arrangement of Specifications of the American Engineering Standards Committee and Division XII on Performance Tests of Rubber Products of Committee D-11 on Rubber Products of the American Society for Testing Materials.

He has been consecutively active on the committees of the Indiana, Buffalo and Metropolitan Sections. After service on the Papers Committee and other committees, he was elected Treasurer of the Metropolitan Section in the spring of 1923 and was re-elected the following year. At present he is Vice-Chairman of the Section and chairman of the Papers Committee.

J. F. Winchester

Councilor Winchester was born at Walpole, Mass., on Dec. 13, 1885, and received his education in the public schools of New England. He learned the machinist trade at the Vaughan Machine Co., Peabody, Mass., and

subsequently was employed by the Upton Machine, Waltham Automobile and Machine Sales Companies and other organizations as machinist, tool maker, inspector and foreman on the earliest models of automobiles, imported and experimented with in this Country. During this period Mr. Winchester studied mechanical engineering and similar subjects allied with the automobile industry in the evening schools of New England and at the Boston Young Men's Christian Association as well as pursuing correspondence courses.

With this experience and training as a background he was employed in May, 1910, by the Hewitt Motor Co. as factory and service inspector, his duties being to pass on the construction of all 5 to 10-ton trucks built by this organization. In April, 1913, he left the Hewitt Company to enter the service of the Standard Oil Co. of New Jersey as sales engineer, specializing in automobile lubricating and sales work. When the growth of the Company's automotive equipment made it necessary to have some one person responsible for its mechanical condition, Mr. Winchester was made automotive engineer and equipment manager and was given the supervision of the Company's sales equipment in New Jersey, Maryland, District of Columbia, Virginia, West Virginia, and North and South Carolina. This is the position that he holds at the present time.

Mr. Winchester has taken an active part in public and semi-public affairs relating to transportation and was one of the organizers of the Motor Truck Club of New Jersey, serving as its secretary for several years and then as its president. For a number of years Mr. Winchester has contributed articles on subjects pertaining to the automobile industry and allied topics to trade and technical periodicals as well as newspapers.

Since his election to Member grade in the Society on June 23, 1919, he has been active in the Society and at the April, 1924, meeting of the Metropolitan Section, Mr. Winchester presented a paper entitled Observations of a Superintendent of Motor-Truck Fleet-Operation. This was based upon his own experience with the Standard Oil Co. For the last year Mr. Winchester has been a member of the Meetings and Membership Committees and of the Highways Sub-Committee of the Research Committee.

Ernest Wooler

Councilor Wooler was born at Farnsworth, Lancashire, England, on Feb. 26, 1888. His technical education was obtained at the Manchester Municipal School of Technology, Manchester, England.

He began his business career in August, 1903, in the drafting room of Royce, Ltd., a firm of electrical and mechanical engineers at Manchester. After a short time Mr. Wooler was transferred to the motor-car department and became an apprentice at the Rolls-Royce, Ltd., plant which was later moved to Derby. He received instruction and worked in every department of the shop. Upon the completion of this course in 1909, he accepted a position in the engineering department where he was engaged in experimental work, engine and chassis design. Leaving Rolls-Royce in October, 1910, Mr. Wooler became designing engineer for Crossley Motors, Ltd., of Manchester, and completed designs for several four and several six-cylinder cars as well as a six-cylinder racing car. In April, 1912, he severed his connection with the Crossley organization and went with Brazill, Straker & Co., of Bristol, builders of commercial vehicles and passenger-cars as assistant chief draftsman.

When the Institution of Automobile Engineers visited this Country in May, 1913, as guests of the Society, Mr. Wooler was one of the party and on completion of the tour began work at the Continental Motors plant in Detroit as designing engineer. He remained there for 2 years, designing engines of various sizes, and in April, 1915, accepted a position as designing engineer for the Chandler Motor Car Co. In July of the following year, he was promoted to assistant chief engineer and shortly afterward started the development of the Cleveland car. While at the Chandler plant and in addition to his regular work on the Chandler car, Mr. Wooler was engaged in the construction of tractors for the Government. Early in 1919, he was appointed chief engineer of the Cleveland Automobile Co. and had complete charge of all engineering connected with this company for the next 6 years. In February, 1925, he became associated with the Timken Roller Bearing Co. of Canton, Ohio, as automotive engineer, and on Jan. 1, 1926, was promoted to chief engineer in charge of all automotive engineering, industrial engineering, service and experimental work.

Mr. Wooler was elected to Member grade in the Society on March 20, 1914. He was a member of the Electrical Equipment and Lighting Divisions of the 1925 Standards Committee and last year served on the Motor-Truck and Passenger-Car Divisions.

T. J. Litle, Jr.

Past-President Litle was born in Philadelphia and was educated at the public schools of that city, the Manual Training High School, the Industrial Arts School, and the University of Pennsylvania. He began his business career as a contractor, installing isolated electric lighting and power plants.

Later, he formed a company to market a high-powered self-intensified gas-lamp. This gas-lamp contained a supercharger that was driven by a motor device of a type identically like the one now used on internal-combustion engines, the motor receiving its energy from the waste heat of the lamp itself. This lamp proved to be the most powerful illuminant of that period. His company, as well as his numerous patents, was taken over by the Welsbach Light Co., Gloucester City, N. J., Mr. Litle becoming chief engineer of the Welsbach Company. During the few years that he held this position Mr. Litle was credited with over 100 inventions. For his researches and development work in gaseous combustion, he was granted a gold medal at the Panama-Pacific Exposition of San Francisco. For a long time, Mr. Litle was actively interested in the American Gas Institute and the National Commercial Gas Light Association and was one of the founders of the Illuminating Engineering Society.

Mr. Litle's connection with the automotive industry dates back to 1917 when he became associated with the engineering department of the Cadillac Motor Car Co. In a few months he advanced to the position of research and experimental engineer and in 1918 he joined the engineering staff of the Lincoln Motor Co. in that same capacity, and subsequently was made chief engineer. After resigning from the Ford organization early last year, Mr. Litle opened offices as an engineering and production consultant, and also became identified with the Copeland Products Co., manufacturer of electric refrigeration in Detroit, where he was vice-president and director of engineering. He largely redesigned the company's product and has 30 patent applications pending on

this work. On Dec. 1, 1926, he came back into the automotive industry as chief engineer of the Marmon Motor Car Co. at Indianapolis.

On March 8, 1919, Mr. Litle was elected to Member grade in the Society. Since that time, he has taken a very prominent part in the activities of the parent society as well as of the Detroit Section. For the administrative year 1923, he was a member of the Meetings Committee, and for the next 2 years he served as its chairman. Besides, he has served on the Research Committee of the Society since 1924. Mr. Litle was a member of the Hardwood Lumber Standardization Committee of the Society in 1924 and 1925 and of the Committee on Standardization Policy in 1926. He also served on the Motor Vehicle Lighting Specifications Sectional Committee of the American Engineering Standards Committee for 1924 and 1926. Last year he was a member of the Non-Ferrous Metals and Tire and Rim Divisions of the Standards Committee. At the 1925 Annual Meeting Mr. Litle was elected First Vice-President and President the following year. For the year beginning May, 1922, he was Secretary of the Detroit Section, and the following spring was elected Chairman of the Section.

At a meeting of the Indiana Section in the fall of 1923, he presented a paper entitled Spring Movement and Vibration Study of Cars in Action. In this paper, Mr. Litle outlined in a most interesting manner some of the methods used to record the movement of the springs of cars as well as the nature and amplitude of the various vibrations. At the November, 1926, Meeting of the Pennsylvania Section he presented a paper entitled the High-Performance Small Car Here and Abroad. This has been widely published in the newspapers throughout the Country and the technical press.

Mr. Litle has lectured before the Taylor Society and the engineering school of the University of Michigan. On several occasions, he has written articles for the automotive press. The principal subject of his articles has been the desirability of perpetuating a fundamentally good design and then augmenting it by refinements that would be completely interchangeable with the old parts. Believing that engineers have much to learn from speed competitions, Mr. Litle has taken a lively interest in both automobile and motorboat racing and has served both on the Technical Committees and as a judge on various occasions. He was recently appointed a member of the contest board of the American Automobile Association.

HELIUM

ON July 1, 1925, pursuant to the act of Congress of March 3, 1925, helium production plant No. 1, near Fort Worth, Tex., with its contributing pipe-line, was transferred from the Navy Department to the jurisdiction of the Bureau of Mines. The Linde Company remained in charge of actual plant operations under contract with the Government but under the general supervision of the Bureau.

In this plant natural gas that comes through the Government-owned pipe-line from the Petrolia gas field, Clay County, Tex., about 104 miles north and west of Fort Worth, is processed for helium. The helium is removed from the gas by operation of a liquefaction cycle, and the gas minus the helium is then returned to the mains for commercial use. The supply of gas from the Petrolia field has been diminishing steadily for some time, so that the plant could be run at only a fraction of its capacity during the fiscal year that ended June 30, 1926. As the fixed charges of plant operation are constant, running at reduced capacity has raised the unit cost of production, or cost per 1000 cu. ft. of helium, notwithstanding the introduction of certain operating economies. The necessity of obtaining further sources of helium-bearing gas is becoming imperative.

During the last fiscal year the members of the board of helium engineers have acted as consultants in the construction of helium production plant No. 2. This plant was designed after experimentation in the cryogenic laboratory at the City of Washington and field trials in a reduced-scale plant to develop a process for producing helium more cheaply and efficiently and is being erected on the Government reservation about 6 miles north of Fort Worth, Tex.

Cooperative work was carried on with the University of Nebraska on problems of importance to helium production and purification cycles. Through use in airships, helium becomes contaminated by double diffusion; helium escapes through the walls of the gas cells and air enters through them. At certain intervals, therefore, the helium supporting an airship must be removed, purified and replaced. A plant for large-scale purification was designed and built at Lakehurst, N. J., for the Navy Department by the Bureau of Mines engineers. The process employed proved so successful that the Army decided to have a smaller mobile purification unit that could be mounted on a railroad car and transported from place to place to serve airships. The Bureau of Mines undertook to design such a plant. Designs for a plant having one-fourth the capacity of that at Lakehurst were perfected, and a plant at McCook Field, Dayton, Ohio, was completed, tested and turned over to the Army for a final tryout at the end of April, the car being sent to Scott Field at Belleville, Ill., near St. Louis, for this purpose. This plant can purify 5000 cu. ft. of helium per hr. for airship use, raising the purity from around 85 to about 98 per cent.

The first vital consideration in the Government's helium project is to provide adequate and constant supplies of helium-bearing natural gas, and to this end the Bureau has maintained a general survey of gas fields to discover and estimate possible sources of such gas.

The New General Motors Institute of Technology

By Albert Sobey[1]

Annual Meeting Paper *Illustrated with* Charts

ABSTRACT

THE new Institute of Technology now being established in Flint, Mich., by the General Motors Corporation represents a movement to provide definitely for the development of the man-power for the Corporation's world-wide organization. Changes in industrial organization and methods during the last generation have lessened greatly the opportunity for the development of employes in the regular processes of industry. As a result, training and development of industrial man-power have become one of the foremost problems of industry. Organized research, experiment and development in the field of training of skill and intelligence of personnel to correlate it with and make experience in the shop systematic and effective is needed for the human phases of industry to correspond with the cooperative effort of the specialized research, design and experimental departments with the production departments in manufacturing organizations.

Training that can best be given in the Institute will be centralized there. The Institute will serve as a central clearing-house for methods, outlines of training courses and the like for training that can best be given at the local units of the Corporation. It will receive reports of progress and suggestions for improvement which will be analyzed and made available to all units. Thus it will serve as a centralizer and coordinator of the cooperative effort of all the units in the field of personnel development.

The program of the new Institute will be built upon that evolved for Flint units by the Flint Institute of Technology during the last 7 years. This provides spare-time courses for present employes and short special full-time training and cooperative courses for incoming employes. The Buick Authorized-Service Course is illustrative of the short full-time training. It is a 12-week course intended to prepare men to become specialists in Buick service. Two cooperative courses are provided, one a 2-year Technical Trades Course for developing tool and die-makers and the other a 4-year Cooperative Engineering Course of college grade for developing junior executives. The work of the new institution should bring material economic and social results in view of the results already obtained in Flint. The social significance of 4 per cent of the City's industrial employes using their spare time during the last term of the Institute in 1926 for personal development is obvious, as is also the value of this as regards industrial morale. Hundreds of men are working their way upward in Flint industries through this program. Results of other phases of the program are equally satisfactory.

ANNOUNCEMENT that a General Motors Institute of Technology would be founded in Flint, Mich., aroused widespread interest and brought inquiries of almost every description. One of the most interesting to me was made by a university professor, who asked:

> Why is the General Motors Corporation going into the school business? It seems to me that this is the work of the regularly organized schools and colleges and that the Corporation has problems enough of its own.

The facts are that the Corporation, in common with all large industrial organizations of this modern age, has problems in plenty and is not entering upon this venture to add to its troubles. In reality, this is not an entirely new venture but is providing a new setting and making a wider application of a program that has been developed in Flint during the last 7 years. Briefly, as I conceive it, the establishment of this Institute of Technology represents a movement to make definite provision for the development of the man-power to meet, in a measure, the pressing personnel problems of the Corporation's organization.

Without question one of the most significant trends of our period is the growing recognition of the importance of the human phases of industry, and one of our great problems is involved in the development and training of the man-power required for our highly specialized industrial order. This affects vitally every phase of industrial operations, from work performed by the new employe just entering the ranks of industry to that of the highest executive. The need for the development of on-coming youth always has existed, and how to meet it has been recognized as the problem for the school. The need for development of men for industrial operations has also been felt, and this has been regarded as a problem of the shop. Meeting of the latter need is one of the serious problems of school administrators and is also demanding the careful consideration of industrial leaders and executives. The situation is not simple.

Industrial Specialization Led to Specialized Training

Our schools and colleges are better organized and are doing better work than a generation ago, yet many of the graduates face difficulties as they try to adapt the training they have received to the highly specialized organizations in which they must find their future. That the problems of training young men for industrial pursuits are recognized clearly by educators is shown by the program of practically every educators' convention.

Within the industries the securing of properly trained employes for various positions requiring skill and ability has become a vital problem, for it involves the morale and effectiveness of the entire organization. The industrial executive finds a very different situation from that presented to his predecessor of a generation ago. Then young men did not look to schools for preparation for advancement in industry and executives did not look to them for trained men for their organizations. Experience was what counted. From the days of the guild period until recently, industry has had in its apprenticeship system a means of training its own personnel for its more highly skilled operations and has offered opportunity for its employes to acquire an all-round expe-

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rience that would prepare them for its own responsible positions of executive and other types. But today specialization is the key to industry. It applies not only to the production worker but extends to the executive and to practically the entire organization. As a result, the apprentice system has been practically wiped out and to a large extent opportunity for a well-rounded experience and training in the regular processes of industry no longer exists. Industrial leaders, therefore, are turning to special agencies to provide training by which employes can qualify for the more highly skilled and responsible positions. Specialization in industry has led to specialization in education and training for industry. The practical school of experience still plays an important part in industrial training but, unless it is correlated, directed and supplemented with the needed technical instruction, it is too haphazard and wasteful of time, effort and human energy.

How Flint Institute's Program Was Developed

Because the higher executives of the General Motors Corporation believe that an organized training-program related directly to their industry and supplementing the practical experience gained through its industrial processes will make possible a more direct means of manpower development, the Corporation has become interested in the educational program that we have had in Flint and has given the new campus and building that will provide the facilities required to extend the program to all General Motors units.

The program of the new Institute will be built upon the foundation program developed in Flint. Leaving the service after the World War, I started the work in an old factory building. Arrangements were made through the Manufacturers Association of Flint to develop an educational and training program for the industrial employes of all the plants in the City under the auspices of an association of the employes which is now known as the Industrial Mutual Association. The first step was to meet an immediate need by some of the employes for spare-time courses of training along lines directly related to the work they were doing in the plants. The extent of this demand is indicated by the fact that in 3 weeks an evening school was in operation with 15 organized courses and 300 students in attendance.

The next step was to formulate a general policy, based on the situation in the industries, upon which solid progress could be built. Investigation showed groups of men here and there who were ambitious for advancement along the lines in which they were then engaged but who had little opportunity, in the specialized nature of their positions, to acquire the needed training. Other men were occupying positions for which they were not well fitted and whose interest lay in other channels with little opportunity to make the change. More elderly men were approaching the end of their productive years in their heavy jobs but could extend their productive period if they were trained for lighter work that involved some skill. There were also foremen who were ambitious to climb to managerial positions, and men of promise who were ambitious to prepare for foremanship responsibilities. In the plants were found still other groups whose greatest possibilities were in office positions, and men in the offices who should be in the shops. On the other hand, the industries were in need of trained tool-makers, die-makers, tool and die designers, foremen and executives, and skilled men for various other types of work.

Twofold Training-Policy Formulated

Out of this situation was formulated the twofold policy upon which the training program was built; first, to organize and offer courses of spare-time training along any line directly or indirectly related to the automobile industry which would be of value to any fair-sized group of employes of any of the industries of the City; second, to organize courses of special training for any position or type of work within the industry for which a demand or need for a fair number of employes existed.

One difficulty presented itself almost immediately in the first phase of the program. This was the differences in education, experience and ability of the men who presented themselves for training in any single course. The range was so wide as to make effective work on any ordinary group-basis almost impossible, hence it became necessary to emphasize individual instruction. Therefore the entire program was organized on a short-unit basis of 12 weeks, with classes meeting 2, 4 or 6 hr. a week. Training required for any line of work was divided into these 12-week units, thus making possible a general classification of the men according to their knowledge and ability.

This general classification required further subdivision, and so emphasis was placed in course organization upon job sheets, lesson sheets and other means of making the work of each student and his advancement in training depend upon his own initiative and ability.

Under this policy more than 200 unit courses of instruction have been organized, covering almost every phase of the automobile industry. These have been arranged in major sequences of broader training laid out for the average student and covering from 1 to 6 years along the major lines of work in the plants. In any individual case these units can be arranged in almost any desired order. Thus it is possible for a representative of a plant to come into the Institute, select the unit of training that he needs for the next step in advance and, using his spare time, build unit upon unit in a flexible program that can be adapted as nearly as possible to his individual needs. In fact, the program is so flexible that it can be changed readily to meet changing conditions in the personal fortunes of the man resulting from promotion and other causes.

Three Full-Time Courses Organized

To meet the needs of the plants insofar as they were not served by the spare-time program, three full-time courses were organized. These are

(1) The Buick Authorized-Service Course
(2) The Technical Trades Course in Tool and Die-Making
(3) The Cooperative Engineering Course

The Service Course was arranged to meet the need for highly skilled men in the service stations of automobile companies throughout the Country. The efforts made in this direction by the commercial automobile schools had been effective. A study convinced us that this was inherent in their method of attempting to cover all makes of car in one general course. We therefore adopted the policy of placing emphasis on the fundamental principles of car construction and modern methods of maintenance and repair with application to the Buick car only. The result has been that the Buick Authorized-Service Course has been strikingly successful; its graduates now fill responsible positions in almost every State of the Union and in 17 foreign countries.

The Technical Trades Course was planned to meet the need for a supply of well trained men in the more highly

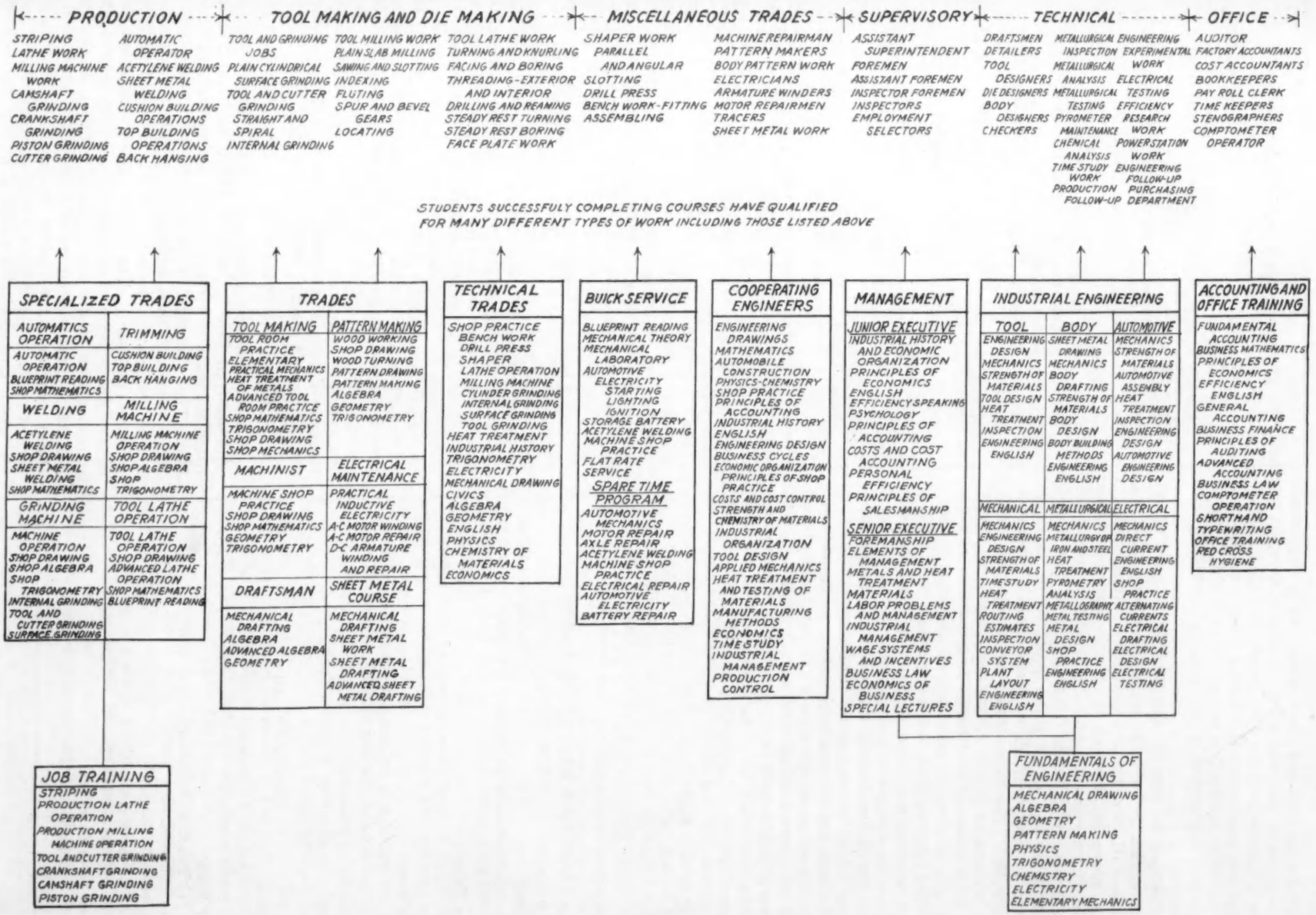


FIG. 1—GENERAL PROGRAM OF FLINT INSTITUTE OF TECHNOLOGY

At the Top Are Listed Representative Jobs for Which Students Have Qualified during the Last Few Years. In the Blocks Below Are Shown the More Important Lines of Instruction and Training. In the Center Are the Technical Trades Cooperative Course, the Buick Service Course and the Cooperative Engineering Course, Which Constitute the Full-Time Program. Those to Left and Right Are Spare-Time Courses, Including 4-Year Specialized Engineering Courses of Night-School Grade and a 6-Year Program of Executive Training

skilled trades of tool and die-making. It is organized on the cooperative plan and offers to boys of from 16 to 18 years of age, who have 10th grade education or its equivalent, an opportunity to obtain a trade training and related technical instruction equivalent to about 2 years of high-school instruction of a specialized technical and trade nature.

The Cooperative Engineering Course is part of a definite program to meet the growing problem of foremen and executives in modern industries. As specialization has increased, demands upon the workmen have decreased but a corresponding and steady increase in demands upon the foremen and executives has come. This constitutes one of the major problems of industry today, and to meet it in Flint, three distinct programs were organized. For men already in foremanship positions or serving as junior executives a number of unit courses were arranged that cover the principles of foremanship, the elements of management and practical economics and cost-control. The training for future executive-material was organized in two separate programs, one for the young men of promise already employed in the industries and the other for young men of the right type coming out of high school.

For the men already employed and who, for economic or other reasons, must work on a regular job, a 6-year program of spare-time courses was organized. This covers, on a night-school basis, 2 years of what we call junior-executive training in such subjects as the historical development of industry; the elements of economics, accounting and costs; and personal-development courses in speaking, personal efficiency and salesmanship. This is followed, for young men who successfully qualify for junior-executive positions, by 2 additional years of senior-executive courses covering foremanship and other activities directly related to industrial organization and management.

Industrial Engineering Course

FIRST YEAR

		Hr. per Week
Fall Term		
D-1	Mechanical Drawing—first term	4
B-3	Geometry	2
Winter Term		
D-2	Mechanical Drawing—second term	4
B-2b	Advanced Algebra—first term	2
Spring Term		
D-3	Mechanical Drawing—third term	4
B-2c	Advanced Algebra—second term	2
Summer Term (8 weeks)		
W-21	Engineering Pattern Making and Foundry Practice	6

SECOND YEAR

Fall Term		
N-1	Practical Physics	4
B-4	Trigonometry	2
Winter Term		
C-1	Practical Chemistry—first term	4
N-1e	Electricity	2
Spring Term		
C-2	Practical Chemistry—second term	4
N-2	Elementary Practical Mechanics	2
Summer Term (8 weeks)		
S-22e	Engineering Machine-Shop Practice	6

FIG. 2—FIRST AND SECOND YEAR PROGRAM OF INDUSTRIAL-ENGINEERING COURSES

Note the Suggested Sequences of the Unit Courses. Every Unit Course Is Given Each Term so That a Student May Start at Almost Any Stage of the Program and Make Almost Any Arrangement of Courses To Meet His Individual Needs

Industrial Tool Engineering Course

THIRD YEAR

		Hr. Per Week
Fall Term		
D-5	Elements of Engineering Design	4
N-3	Elementary Mechanics (Advanced)	2
Winter Term		
D-6	Elements of Engineering Design—second term	4
N-4	Strength of Materials	2
Spring Term		
D-8	Tool Design	4
M-11	Metals and Their Heat Treatment	2
Summer Term (8 weeks)		
S-23e	Engineering Machine-Shop Practice	6

FOURTH YEAR

Fall Term		
D-9	Tool Design—second term	4
R-2	Inspection Tools and Methods	2
Winter Term		
D-10	Tool Design—third term	4
F-1a	Engineering English	2
Spring Term		
D-10a	Tool Design—fourth term	4
F-1b	Engineering English	2

FIG. 3—THIRD AND FOURTH YEAR PROGRAM OF INDUSTRIAL-ENGINEERING COURSES

The Cooperative Engineering Course was organized to supplement this source of supply of future executives with a group of young men more broadly trained technically. The course is a 4-year program of college grade, for admission to which high-school graduation or its equivalent is required and also evidence of good character and some potential leadership-ability. The program, which is conducted on the cooperative plan, with alternate periods of 4 or 8 weeks in the Institute and corresponding periods in the industry, is in reality fourfold in nature. During the Institute periods the training may be classified under two heads: (*a*) fundamental engineering subjects that are common to all college engineering courses and (*b*) specialized training in the principles of industrial organization and management. During the work periods the student is given a directed practical experience in industrial operations, which also gives him contact with and a knowledge of industrial men. This program has been in operation for 3 years with a considerable degree of success. It is in reality a college-grade course in management engineering.

RANGE AND SEQUENCES OF UNIT COURSES

A more definite conception of the program can be obtained from Fig. 1. In the blocks in the lower part are listed the more important lines of instruction and training. The Technical Trades Cooperative Course, the Buick Service Course and the Cooperative Engineering Course are given in the center of this group. This is the full-time program. The others listed are spare-time courses and cover a wide range, from short job-training courses shown at the left to six, now seven, 4-year specialized engineering courses of night-school grade and a 6-year program in executive training. In the upper part of the diagram is given a representative list of jobs for which students have qualified during the last few years.

The flexibility of the spare-time program is emphasized

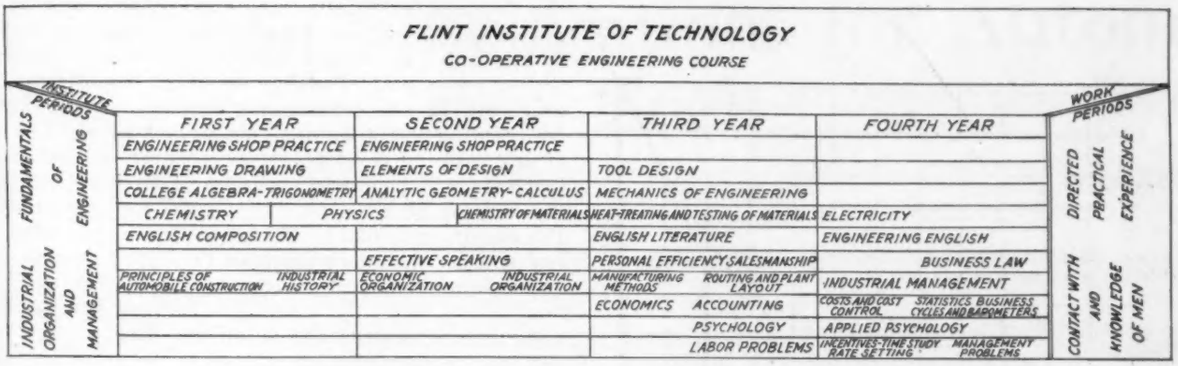


FIG. 5—PROGRAM OF COOPERATIVE ENGINEERING COURSE

This Is a Management Engineering Course with a Close Correlation of Training in the Institute with Actual Practice in the Plant under Some Executive of a Major Department Who Advises with the Institute Staff Regarding the Training Program

B—Junior Executive Course

FIRST YEAR

Fall Term		Hr. Per Week
Fm-3a	Outlines of Industrial Development	4
F-1b	Effective English (Advanced)	2
Winter Term		
Fm-3b	Practical Economics	4
F-2a	Effective Speaking	2
Spring Term		
Bm-2	Principles of Psychology	4
F-2b	Effective Speaking (Advanced)	2

SECOND YEAR

Fall Term		
Gf-1	Fundamentals of Accounting	4
Bm-1	Personal Efficiency	2
Winter Term		
Gf-2	Fundamentals of Accounting	4
Bm-1a	Principles of Salesmanship	2
Spring Term		
Fm-3c	Fundamentals of Cost and Cost Control	4
Bm-3	Principles of Instruction	2

C—Senior Executive Course

FIRST YEAR

Fall Term		
Gm-1a	Foremanship	2
Cm-1	Materials of Engineering (Iron and Steel)	2
Winter Term		
Gm-1	Elements of Management	2
Cm-2	Materials of Engineering (Non-Ferrous)	2
Spring Term		
Gm-3	Labor Problems and Management	2
Bm-4	Technique of Executive Control	2

SECOND YEAR

Fall Term		
Gm-4a	Industrial Management—first term	2
G-20	Business Law	2
Winter Term		
Gm-4b	Industrial Management—second term	2
G-21	Business Law	2
Spring Term		
Fm-3d	Business Cycles and Statistics	2
Gm-5	Modern Industrial Tendencies	2

FIG. 4—FIRST AND SECOND YEAR PROGRAMS FOR JUNIOR AND SENIOR EXECUTIVES

by Figs. 2, 3 and 4, which show the way in which the unit courses are arranged in suggested sequences. Every unit in some of these sequences is given each term to make it possible for an ambitious man to begin his work at almost any stage of the program and make almost any arrangement of courses that may be necessary to meet his individual needs. Frequently students with widely different objectives come together in one unit for a given term and then branch away again as they continue their work.

SERVICE COURSE A SUCCESS

Possibly the best endorsement that the Buick Authorized-Service Course has received has been its adoption by the General Motors Export Co. to train its service men and also to give a technical training to men for its sales organization. Since the Export Company handles all makes of General Motors Cars, the adoption of a special Buick course after very careful testing by the officials of the Company, is a rather clear indication of the value of the fundamental training given and evidence of the correctness of the principles of instruction. It is planned to extend this service-training program to all General Motors cars in the new institution.

The outline of the program of the Cooperative Engineering Course in Fig. 5 is of special interest to men who are familiar with the problems of the automobile industry as related to leadership and men for responsible executive-positions. This course has been developed with the active cooperation of an advisory committee of leading executives of the plants of Flint. Its purpose is to prepare young men of the right type for future executive-positions. It is really a management-engineering course with a close correlation of training and practice through connection of the Institute with the factory system. Not later than the junior year, and in many cases earlier, students are placed under the direction of some executive of a major division of our industries and are recognized as his men. From this point on he advises with the Institute staff regarding their training program with a view to having it of such a practical nature as to make the men most valuable for his own organization upon completion of their training.

The courses given during the Institute periods are organized also in what we term horizontal sequence. In many cases they are conducted so as to give direct contact and experience with corresponding factory problems in the Flint units, with factory executives cooperating with the regular instruction staff to make the instruction as vital and uptodate as possible.

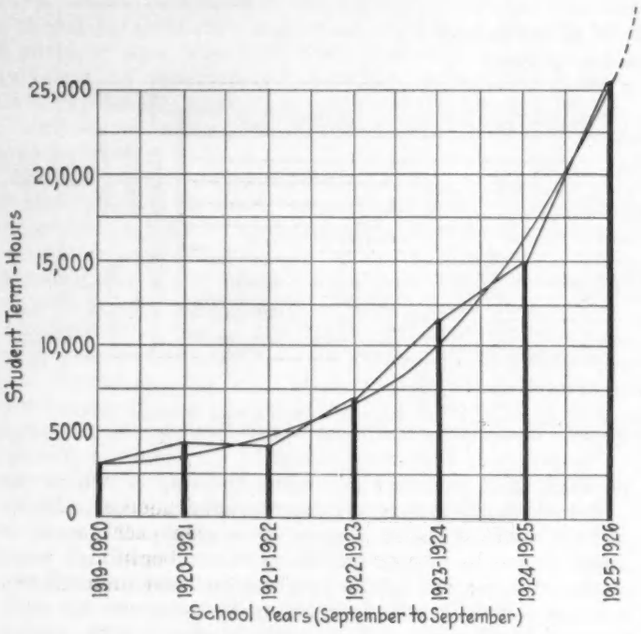


FIG. 6—GROWTH OF THE FLINT INSTITUTE OF TECHNOLOGY DURING 7 YEARS

The Growth Is Charted in Student Term-Hours and Reached a Rate Last Year Which Made It Evident That Existing Facilities Would Be Taxed to Capacity in Another Year. Discussion of the Situation with the Late H. H. Bassett, Then President of the Buick Motor Co., Finally Resulted in the Decision of the Executive Committee of the General Motors Corporation To Utilize the Institute for Development of Personnel for All Units of the Organization and To Provide a 10-Acre Campus and a New Building with 65,000 Sq. Ft. of Floor Area Which Is Now Nearing Completion

RAPID GROWTH MADE EXPANSION NECESSARY

The increasingly rapid growth of the Institute is presented graphically in Fig. 6. It reached a rate last year that made it evident that one more year at most would see the present facilities taxed to capacity. This condition was discussed with the late H. H. Bassett, president of the Buick Motor Co., with a view to determining what additional facilities could be obtained. Mr. Bassett finally decided that the service rendered to the Flint units was sufficiently valuable to warrant asking the Executive Committee of the General Motors Corporation for an appropriation to provide a building and the necessary campus to continue the development of the program. This was done at the May meeting of the Committee, held in Flint in connection with a visit of investigation and inspection to the school. As a result, it was decided to extend the advantages of the Institute to all the units of the Corporation outside of Flint as well as in the City, and to change the name to the General Motors Institute of Technology to indicate more definitely the enlarged scope. The size of the campus as originally contemplated was tripled to provide room for future expansion.

The new building is rapidly nearing completion. It will have approximately 65,000 sq. ft. of floor area on three floors. The first floor will be devoted to mechanical laboratories, a machine-shop and a service station; the second floor to general offices, a library, physical, chemical, metallurgical and electrical laboratories, and a large assembly hall and gymnasium; while the third floor is to be devoted to drawing, class and study rooms.

The general policy on which the program of the larger institution is now being worked out follows much the same lines as that which proved successful for Flint. Courses that can best be centralized in the Institute itself will be given there. This will, of course, include the Cooperative Engineering Course, to which students are already being sent by all the car-producing units and by the units at Dayton, and also the service and other training courses. Possibly of more significance, however, will be the centralizing function of the Institute for training activities in all the units whereby the results of any training development or research conducted at the Institute will be made available to all the units of the Corporation on what may be termed an extension basis. The results obtained in the use of these programs, or of any special training-programs developed in any of the units themselves, will be reported to the central institution, where they will be analyzed and put into such form as to make them valuable to all the other units. In this way will be developed an extension program of training that will cover all the major personnel-development problems of the Corporation in a form that reflects the combined experience of the entire organization.

SIGNIFICANT RESULTS OF FLINT PROGRAM

It would be interesting to estimate the results that may accrue from the enlarged program. The results of the Flint program are before us in definite form. A remarkably large percentage of the graduates of the Buick Authorized-Service Course are already serving in responsible positions as service managers, service salesmen, service foremen, and so on after only 3 years of operation. The Cooperative Trades Course is contributing to the solution of the problem of obtaining skilled craftsmen, and the upper classmen of the Cooperative Engineering Course are in demand throughout the plants.

The results of the spare-time training program are significant. I could tell of men who have improved their positions in life and are working their way up in the plants, ranging from the young man just beginning his climb to the man who came to us 7 years ago as a 10th-grade graduate with limited experience in the shop, undertook a heavy schedule of training covering practically the entire 7 years and now has been transferred to a $10,000-a-year position.

These results have not only an economic significance to the individuals and to the companies; they also have a broad social significance. In view of much that has been said regarding the deadening effects of the monotony of specialized operations in modern industry, the fact that the Institute has had more than 12,000 students from our plants enrolled in its spare-time courses during the last 7 years means considerable. That the proportion of the employe personnel has been increasing until this last term the enrollment reached 1250, or 4 per cent of the entire employed personnel of the Flint factories also is significant.

As we look forward to the establishment of the new General Motors Institute of Technology, we are hoping that it will mean to employes of Flint and all General Motors units an opportunity to use their spare time for preparation for advancement to a broader, more satisfying life. We hope that to young men of other communities who are coming up through the schools and looking to industry as their field of life work, it will offer a means of direct practical and yet broad training for success. We hope that it will represent to the Corporation a source of trained help and of broad and resourceful leadership and a means of maintaining morale and a cooperative spirit in all branches of its organizations. But, more significant, because it is the basis of all these, we hope that the Institute will be known widely as a developer of industrial man-power and a builder of men.

Detonation Specifications for Automotive Fuels

By GRAHAM EDGAR[1]

ANNUAL MEETING PAPER

ABSTRACT

TENDENCY to detonate is probably the most important factor in determining the usefulness of fuels for internal-combustion engines. Although it is possible, by various means, to measure more or less accurately the relative knocking characteristics of fuels, no way has heretofore been found of rating fuels that does not depend upon some arbitrary non-reproducible conditions and measurements. The general methods adopted have consisted in comparing one fuel with another, but no absolute standard has been available.

Knocking is a function of several variables, the knocking characteristics of which have been found by keeping a certain number of them constant while certain others are varied, thus rating them in terms of load, the spark-advance necessary to produce knocking, the position of the throttle at which knocking begins, and the like. A second method consists in keeping all operating factors constant and comparing the fuels in terms of some non-knocking fuel, such as benzol, or some antiknocking fuel, such as tetraethyl lead, which must be added to the poorer of two fuels to make its knocking characteristics identical with those of the better one.

To draw detonation specifications for fuels, a reproducible primary standard fuel must be developed and methods of comparing fuels must be agreed upon. The composition of gasoline is so complex and the knocking characteristics of its different constituents are so varied that great difficulty has been encountered in finding one or more hydrocarbons, the purity of which could be definitely established by test and which would thus be absolutely reproducible.

Two hydrocarbons are cited that seem to be ideally suited for standard reference fuels, namely, pure normal heptane C_7H_{16} and pure octane C_8H_{18}, which is prepared synthetically from tertiary butyl alcohol. By mixing these two hydrocarbons in different proportions it is said to be possible to duplicate the knocking characteristics of any commercial fuel between the limits of 60 per cent of heptane and 40 per cent of octane and 40 per cent of heptane and 60 per cent of octane. These hydrocarbons are also said to be almost identical in volatility, chemical composition and other physical properties, and that, consequently, irregularities are not to be feared.

To make possible the drawing of detonation specifications for automotive fuels, it is therefore necessary only to specify that the knocking characteristics of a fuel for a given purpose should be equivalent to those of a mixture of any desired proportions of the heptane and octane in question and to agree upon one method of testing or some one of a number of methods that may be satisfactory.

RESEARCH engineers have realized for some time that the tendency of a fuel to detonate or knock is probably the most important single factor in determining its usefulness for internal-combustion engines. In the report of the Empire Fuels Committee of Great Britain, 1924, the conclusion is reached that

> It has been proved that the tendency of a fuel to detonate is the one outstanding factor in determining its value for use in internal-combustion engines. Compared with this all other considerations are of secondary importance.

These facts are now generally realized by fuel producers, automobile builders and the public, as is evidenced by the great interest displayed in fuels having a relatively low tendency to detonate. The problem of rating different fuels with regard to their tendency to detonate and establishing detonation specifications for fuels designed to meet special conditions thus becomes exceedingly important. Although it is possible, by a variety of means, to measure with more or less accuracy the relative knocking characteristics of fuels, no way has been found of rating these fuels in a way that does not depend upon some arbitrary non-reproducible conditions and measurements; and until such a way has been devised, no definite specifications for the knocking characteristics of automotive fuels can be drawn. It is my intention to discuss various aspects of this problem and to propose what seems to be a satisfactory solution.

METHODS OF MEASURING KNOCKING CHARACTERISTICS

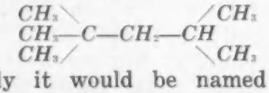
It should be emphasized at the start that all methods of measuring knocking characteristics that have been developed so far are essentially methods of comparing one fuel with another and do not give absolute results independent of the arbitrary method of measurement. The actual amount of knocking that develops from a given fuel is a function of several variables such as the compression-ratio; the fuel-air ratio; the temperature of the charge; the temperatures of the cylinder-walls; the timing of the spark; the design of the cylinder-head and the position of the spark-plug, valves and the like; the materials of which the cylinder and the piston are composed; the cleanness of the cylinder and the piston; the humidity; the barometric pressure; and the amount of leakage at the valves and the blow-by at the pistons. By keeping some of these factors constant and varying others, it is possible to measure the relative knocking characteristics of different fuels in any one of a variety of ways. Thus, the load may be increased until knocking begins, and two fuels may be compared in terms of such load. The load may be kept constant and the spark advanced until knocking begins, and the two fuels may be rated in terms of the spark-advance necessary to bring about such knocking. The throttle may be opened gradually and the position at which detonation begins may serve to rate the fuels under comparison. Another method consists in keeping all operating factors of the engine constant and comparing two fuels in terms of the amount of some non-knocking fuel, such as benzol, or some antiknocking material, such as tetraethyl lead, which must be added to the poorer of two fuels to make its knocking characteristics identical with those of the better one. All such methods, however, while useful for certain specific purposes, give results that are not translatable into any absolute terms, since there is no way of defining the knocking characteristics of whatever fuel is used as a reference standard.

[1] Ethyl Gasoline Corporation, New York City.

An analysis of existing data makes it clear that before it will be possible to draw up detonation specifications for fuels, two problems must be solved. The first of these is the development of a reproducible primary standard fuel with which the reference fuels of different laboratories can be compared; the second is an agreement upon a method or methods of comparing fuels that will give reasonably reproducible results.

Standard Fuels

Experience has shown that it is impossible to prepare samples of gasoline having definite knocking characteristics. The composition of gasoline is so complex and the knocking characteristics of its different constituents are so varied, that the task of establishing any such material as a reproducible standard seems hopeless. Ideally, the standard mixture should be composed of one or more hydrocarbons, the purity of which can be definitely established by test and thus will be absolutely reproducible. Unfortunately, hydrocarbons having properties suitable for such a standard have not been available. It has been proposed to use mixtures of toluene and ether, but all such mixtures are open to serious objections. In the first place, their physical properties differ widely from those of the gasoline that it is desired to measure; in the second place, their differences in volatility are so great that irregular results are likely to be obtained whenever vaporization is not complete and uniform. Investigation in the laboratory of the Ethyl Gasoline Corporation has resulted in the development of two pure hydrocarbons that seem to be ideally suited for a standard reference-fuel. One of these, C_7H_{16}, is pure normal heptane. This material can be prepared from Jeffrey pine oil in a state of absolute purity. Its physical properties are as follows: boiling-point, at 760 mm., 98.4 deg. cent. (209.1 deg. fahr.), corrected; specific gravity, at 20.0 deg. cent. (68.0 deg. fahr.), 0.6847; viscosity, at 18.5 deg. cent. (65.3 deg. fahr.), 0.00427. It shows a tendency to knock that is much more pronounced than that of any automotive fuel at present used. The other pure hydrocarbon is an octane, C_8H_{18}, prepared synthetically from tertiary butyl alcohol. Its structural formula is



and scientifically it would be named 2.4.4 trimethyl pentane. Its physical properties are as follows: boiling-point, at 760 mm., 99.3 deg. cent. (210.7 deg. fahr.), corrected; specific gravity, at 20.0 deg. cent. (68.0 deg. fahr.), 0.6914; viscosity, at 18.5 deg. cent. (65.3 deg. fahr.), 0.00543. Although it is, like heptane, a paraffin hydrocarbon, it shows very little tendency to knock, being comparable in this respect with benzol. It is possible by mixing these two hydrocarbons in different proportions to duplicate the knocking characteristics of any commercial automotive fuel. The entire range of automotive fuels may be duplicated between the limits of 60 per cent of heptane and 40 per cent of octane and 40 per cent of heptane and 60 per cent of octane.

The two hydrocarbons that it is proposed to use for the preparation of a basic reference-fuel are almost identical in volatility, chemical composition and other physical properties. Irregularities in measurement, due to unequal vaporization and change in the fuel-air ratio with changing proportions of the two, are therefore not to be feared.

Detonation Specifications for Engine Fuels

Detonation specifications for automotive fuels become possible by the development of the new standard fuel. It is necessary only to (*a*) specify that the knocking characteristics of a fuel for a given purpose shall be equivalent to those of a mixture of any desired proportions of the heptane and octane in question, and (*b*) agree upon one method of testing, or some one of a number of methods that may prove to be equally satisfactory. Thus, United States motor gasoline might be required to be at least equal in knocking characteristics to a mixture of 55 per cent of heptane and 45 per cent of octane, while fuels designed for use in high-compression engines might be required to equal 45 per cent of heptane and 55 per cent of octane. Fuels for airplane use, racing or other special purposes might be required to equal any given mixture that experience has proved to be satisfactory. The problem of settling upon one or more satisfactory methods of comparing two fuels should be relatively simple. Cooperative research is under way at the present time among a number of laboratories, including that of the Bureau of Standards, on different methods of testing; and it seems probable that this part of the problem will be relatively easy of solution. So long as a satisfactory standard-fuel is available, no difficulty should be encountered in solving the much discussed question of definite specifications for the knocking characteristics of fuels. At present, only relatively small quantities of the two pure hydrocarbons in question have been prepared, but there should be no difficulty in obtaining them in any desired quantity. It is probable that they will be always be too expensive to be used for routine testing, but such testing is not necessary for drawing specifications. It is probable that each laboratory will continue to use as a working-standard some given sample of gasoline or a blend of gasolines. All that will be necessary to make their results interpretable will be to determine from time to time the rating of such working-standards in terms of the primary standard of pure hydrocarbons. I believe that the standard fuel outlined above offers for the first time the possibility of writing definite specifications for the knocking characteristics of automotive fuels.

Vol. XX February, 1927 No. 2

A Four-Speed Internal-Underdrive Transmission

By C. A. Neracher[1] and Harold Nutt[2]

Annual Meeting Paper *Illustrated with* Charts, Drawings and Photograph

ABSTRACT

ALTHOUGH the enormous demand for automobiles has been met with continual improvement in performance, economy, comfort, and appearance of the vehicle, the development of the transmission has lagged badly for more than a decade. Car-ability has been handicapped by the limitations of the three-ratio gearbox. Notwithstanding that the added car-flexibility, economy and smoothness that result from increasing the number of ratios between the engine and the axle have long been appreciated by engineers, the shortcomings of conventional four-speed transmissions, friction drives and two-speed rear-axles having double ring-gears and pinions are many, and the first cost and lack of over-all efficiency of the gasoline-electric drive have prevented their greater use in passenger-car and truck service. The reasons for the failure of the present four-speed transmissions to give satisfaction are cited, and stress is laid on the need of reducing the maximum engine-speed while at the same time maintaining or improving the over-all car-ability.

A description is then given of a four-speed transmission by which the gasoline consumption, as indicated by road tests, is said to show a saving of approximately 20 per cent. The assembly consists essentially of a three-speed gearbox on the forward end of which is housed an internal-gear unit that provides a reduction of approximately 1.4 to 1.0 for the third-speed ratio. Shifting from third to fourth or from fourth to third is accomplished by a hollow metal-clutch, the tooth arrangement of which allows the maximum angular-motion of 40 deg. between the mating parts. The shift can, therefore, be made with ease regardless of the car speed. It is pointed out that this is of prime importance if the advantage of an additional ratio is to be realized. Tables and curves show the comparative performance of passenger-cars and trucks equipped with the four-speed internal-underdrive transmission and with the three-speed gearbox.

The conclusion is reached that, if no other advantage existed, the gasoline economy effected by the use of an additional gear-ratio would justify the expenditure of effort required to develop a successful product.

THE enormous growth of the automobile industry since its birth some 25 years ago is a fact of which automobile engineers can be justly proud. Although this phenomenal growth has in the main been caused by the demand of the public for automobiles, nevertheless this demand would not have reached its present colossal proportions had not those engaged in design and production endeavored year after year to make better vehicles. There has been continued improvement in performance, economy, comfort, and appearance.

Unfortunately, however, the advancement of the major units of the automobile has not been uniform. Engine, axle, frame, and body design has progressed rapidly. Within the last 2 years a distinct improvement in brake equipment has taken place. On the other hand, transmission development has lagged badly for nearly a decade. True, there has been some progress in the direction of quietness of operation and decrease in size, but car ability is as badly handicapped today by the limitations of a three-ratio gearbox as it was years ago.

The desirability of having more than three forward gear-ratios need hardly be debated. The added car-flexibility, economy and smoothness of operation that result from increasing the number of ratios between the engine and the axle have long been appreciated by engineers.

Requisites of a Four-Speed Transmission

To meet public approval and to possess genuine utility, a four-speed transmission must possess all the following characteristics. The shift from third to fourth or from fourth to third-speed must be accomplished with the utmost facility at any car-speed. The ratio that is not direct-drive must be efficient in order that economy in engine operation, attainable by the use of a fourth-speed, shall be realized. And of great importance is quietness of operation in both the third and the fourth ratios. The degree of quietness should be such that an average car-operator could not determine from the noise of the transmission whether the car was being driven in the geared or the direct-drive ratio.

The most common and one of the most unsatisfactory methods of approaching this problem is to use a four-speed transmission having spur-gears for all the ratios except the direct-drive. Such units are generally disappointing. Of the two top speeds the one that is geared is entirely too noisy for passenger-car purposes and has power losses through the reduction that largely offset the advantages of an additional ratio. Moreover, the shift from third to fourth or from fourth to third-speed cannot be satisfactorily made if spur-gears must be slid into engagement, on account of the relatively high pitch-line velocities of the teeth at the car speeds at which these shifts must be made. This objection can be overcome if constant-mesh gears are used for the upper ratios and the shifting is accomplished by metal clutches; but the problem of noise is augmented because of the additional constant-mesh gears. Unfortunately, at present there is no commercial method of producing spur-gears that, according to accepted standards, are suitably quiet for passenger-car service, when operated continuously under load.

Friction-Disc Drives

Friction-disc drives have not been commercially successful in automobile applications, mainly because of mechanical limitations. The method of power transmission through discs placed at right angles to one another is fairly efficient and has always had the attraction of an unlimited range or ratios. Difficulties of maintaining the friction surfaces in suitable condition and of providing adequate shaft and bearing sizes to take the heavy loads of this arrangement have resulted in its general

[1] Chief engineer, Durant Motors, Inc., Elizabeth, N. J.
[2] M.S.A.E.—Engineer, Durant Motors, Inc., Elizabeth, N. J.

abandonment for all except very light-weight automobiles.

Gasoline-Electric Drives

Gasoline-electric drives have been used to a small extent in passenger-cars, but, although possessing some highly desirable features, this method of power transmission is at present used only in heavy vehicle-units, such as motorcoaches or motor rail-cars. This is as much as we should expect it to be, since the cost of the electrical equipment in the drive is high, when compared with that of a conventional transmission; and electrical units are generally less efficient in small than in large sizes. For heavy-vehicle service, the gasoline-electric drive has several distinct advantages over mechanical methods and these are in a large measure responsible for its success in that field.

Double Ring-Gear and Pinion

Efforts to obtain a double direct-drive by the use of two ring-gears and pinions in the rear axle have not been a permanent commercial success. The object of building the additional ratio into the rear axle has been to provide two top gear-ratios both of which would be quiet and efficient. Although this end has been successfully attained, heavy first-cost, complication in gearshifting, mechanical troubles with the bearings, and serious increase in axle weight have been some of the obstacles to further progress along this line.

The choice of the rear axle for the location of a ratio-change unit, however, has several advantages. Most important of these is that a certain amount of noise can be tolerated at this point, because it is not so easily heard inside an automobile as it is when coming from a transmission directly beneath the floorboards. The transmission location, however, possesses the advantage of more simple application of the control of all shifts with a single lever. Nevertheless, there are a number of methods by which the shift of the undergear unit mounted on the rear axle can be made by the regular transmission hand-lever. The rear-axle location of this unit also allows the standard three-speed gearbox to be retained, all modifications being confined to the rear-axle assembly. Consequently, much development along this line may be anticipated.

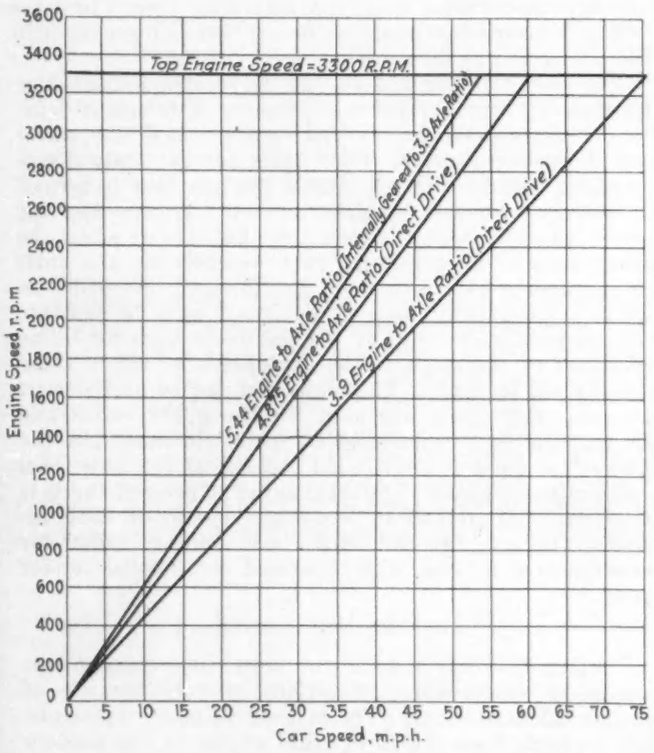

Top Engine Speed = 3300 R.P.M.
5.44 Engine to Axle Ratio (Internally Geared to 3.9 Axle Ratio)
4.875 Engine to Axle Ratio (Direct Drive)
3.9 Engine to Axle Ratio (Direct Drive)
Engine Speed, r.p.m.
Car Speed, m.p.h.
0 200 400 600 800 1000 1200 1400 1600 1800 2000 2200 2400 2600 2800 3000 3200 3400 3600
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75

Fig. 1—Comparative Curves of Engine-Speeds and Car-Speeds for Three Different Gear-Ratios

The 4.875 Axle-Ratio, Which Is Standard on Cars Having Three-Speed Transmissions, Requires an Engine-Speed of 3280 R.P.M. for a Car Speed of 60 M.P.H. On the Other Hand, the 3.9 Ratio Used for the Direct-Drive Fourth-Speed Gives an Engine-Speed of 2620 R.P.M. for a Car Speed of 60 M.P.H.

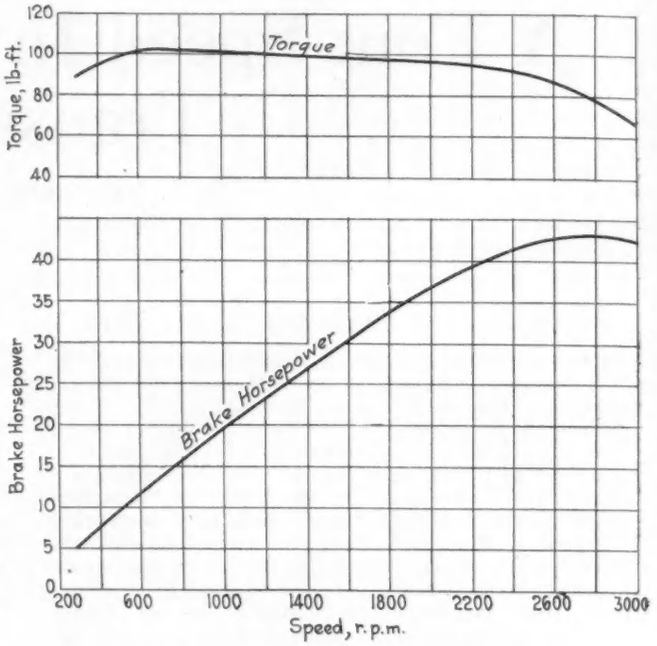


Fig. 2—Brake Horsepower Curve of Model-R Engine

With the 3.9 Ratio, the Engine-Speed of 2620 R.P.M. Is Near the Point at Which the Maximum Horsepower is Being Developed and Consequently at Which the Maximum Car-Speed Is Attained

Excessive Engine-Speeds and High Axle-Ratios

Handicapped by the lack of more than three forward gear-ratios, the industry year after year has met the popular demand for better acceleration and hill-climbing ability by a gradual increase in the rear-axle ratios. At present, axle ratios in the neighborhood of 5 to 1 are common practice. Wheel sizes, moreover, have steadily decreased, yet the maximum car-speeds are higher than ever. The effect on the top engine-speed is unquestionably serious. At 60 m.p.h. crankshafts are turning more than 3000 r.p.m. The inertia forces of the connecting-rods and pistons at such speeds are terrific. It is not, therefore, unreasonable to suspect that the additional expense of building an engine to withstand the punishment that it must take at top car-speed is unwarranted, provided that equal or better car-performance can be realized by the use of an additional ratio in the transmission.

A fortunate but none the less unpleasant effect of operating an automobile engine at maximum speed is the audible distress that it exhibits. The powerplant is generally too noisy and often too rough to make wide-open-throttle driving on a level road even moderately enjoyable. At speeds of more than 3000 r.p.m., even the best designed and best constructed engines of the sizes ordinarily used in American cars are anything but agreeable to the ear.

Variation of Engine-Speed with Car-Speed

Fig. 1 shows engine-speeds compared with car-speeds for three different gear-ratios. The 4.875 axle-ratio, which is standard on the car with the three-speed transmission, requires an engine-speed of 3280 r.p.m. for a car speed of 60 m.p.h. Although this ratio was considered necessary to give the acceleration and hill-climbing ability desired, it is apparent that the powerplant used is not well adapted to give the maximum car-speed, as the horsepower available at this high engine-speed is noticeably below the peak of the horsepower curve of Fig. 2. On the other hand, the 3.9 ratio used for the direct-drive fourth-speed gives, at 60 m.p.h., an engine-speed of 2620 r.p.m. This is close to the point at which the maximum horsepower is being developed and, consequently, at which the maximum car-speed is attained.

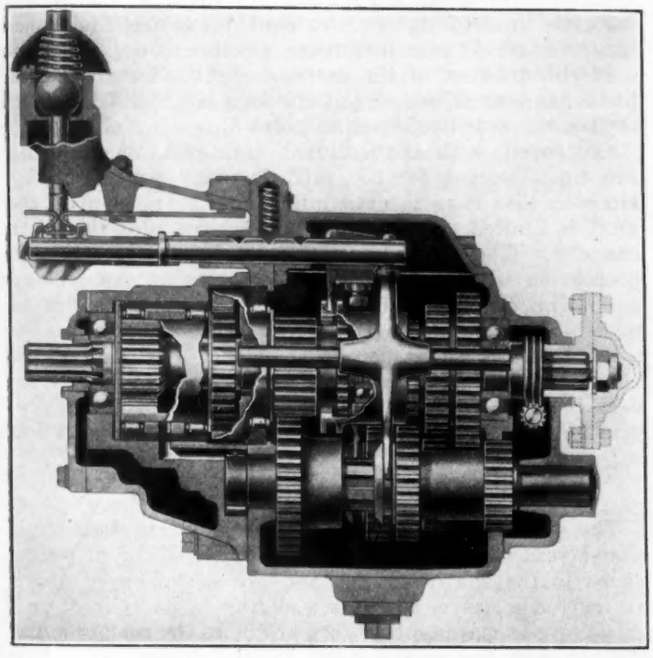


Fig. 3—Sectional Assembly of a Four-Speed Transmission
In a Cylindrical Housing at the Forward End Is an Arrangement of Internal Gears by Which a Quiet and Efficient Third-Gear Is Obtained, the Fourth Speed Being the Direct Drive. For Third-Speed, the Drive Is from the 17-Tooth Pinion at the Front End of the Main Shaft to a 21-Tooth Internal-Gear on the Inside of a Sleeve Surrounding the Main Shaft. At the Other End of This Sleeve, on Its Outer Surface, Is a 31-Tooth External Gear Engaging a 35-Tooth Internal Gear That Is Carried in a Cup-Shaped Forging

With an additional usable ratio in the transmission, the necessity for extremely high engine-speeds disappears. A direct-drive fourth-speed ratio can be selected that will decrease the engine-speed from 20 to 30 per cent for any given car-speed, maintaining at the same time sufficient ability to carry the car up ordinary grades without recourse to the third-gear. It should be borne in mind that the inertia loads on the engine bearings vary as the square of the speed and that the same is roughly true of the volume of noise. Consequently, a reduction in speed of say 25 per cent means a reduction of inertia bearing-loads and noises of about 50 per cent, a gain of no mean proportions. The experience of driving a car equipped with a four-speed transmission in a quiet third gear-ratio between the engine and the rear wheels of about 5.4 at 35 m.p.h. and then making the shift to a direct-drive fourth-speed on a 3.9 axle-ratio is a revelation. There is a sensation of almost complete elimination of engine noise. The car seems to float along effortless, much as it does when coasting. The gains in smoothness and quietness are equally great in either a four or a six-cylinder installation. The low final-ratio in the axle could not be used, of course, unless a quiet third-gear were available at the will of the driver, that duplicated or improved the acceleration and hill-climbing-ability standards as they now exist. It was with the above objectives in mind that the transmission about to be described was designed.

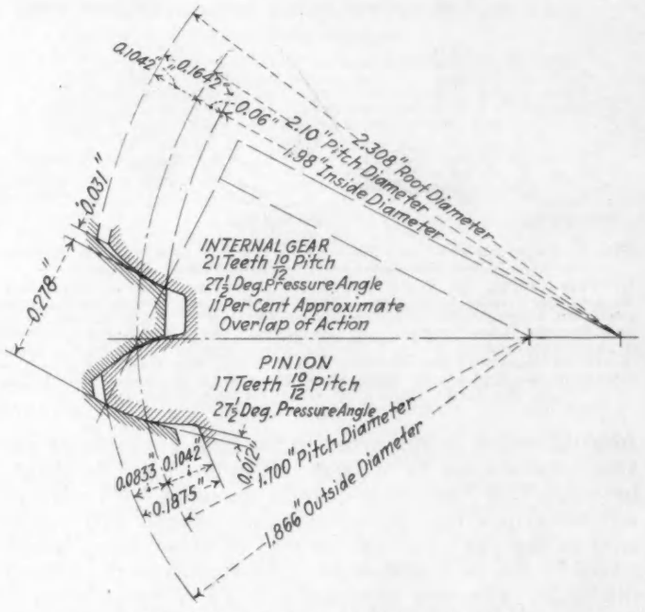


Fig. 4—Investigation of Tooth Motion
The Internal Gear Has 21 Teeth, 10 to 12-Pitch and 27.5-Deg. Pressure-Angle. The Overlap of Action Is Approximately 11 Per Cent. The Pinion Has 17 Teeth, 10 to 12-Pitch and 27.5-Deg. Pressure-Angle

Internal-Gear Assembly

Fig. 3 shows a sectional assembly of a four-speed transmission having, in a cylindrical housing at its forward end, an arrangement of internal gears by which a quiet and efficient third-gear is obtained, the fourth-speed being the direct drive. For third-speed, the drive is from the 17-tooth pinion at the front end of the main shaft to a 21-tooth internal gear on the inside of a sleeve surrounding the main shaft. At the other end of this sleeve, on its outer surface, is a 31-tooth gear, which engages a 35-tooth internal gear carried in a cup-shaped

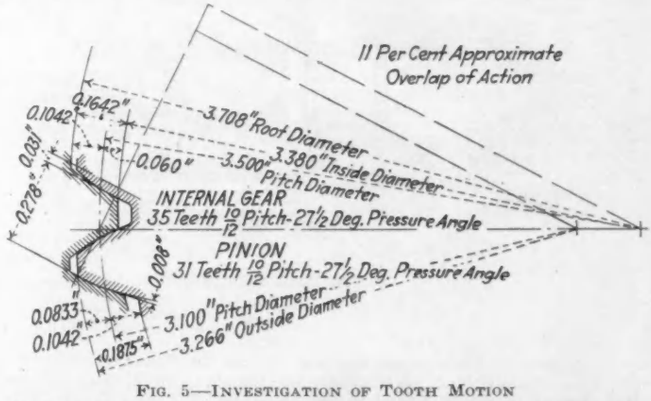


Fig. 5—Investigation of Tooth Motion
The Internal Gear Has 35 Teeth, 10 to 12-Pitch and 27.5-Deg. Pressure-Angle. The Overlap of Action Is Approximately 11 Per Cent. The Pinion Has 31 Teeth, 10 to 12-Pitch and 27.5 Deg. Pressure-Angle

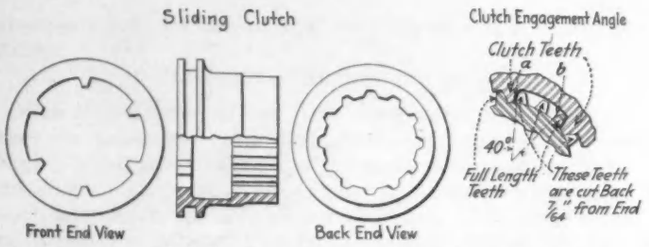


FIG. 6—CROSS-SECTION AND TWO END-VIEWS OF THE HOLLOW SLIDING CLUTCH; AND THE CLUTCH-ENGAGEMENT ANGLE

In This Clutch, 12 Teeth 1 3/32 In. Long Are Cut on the Rear End of the Inside Diameter. These Support the Sleeve and Are in Constant Engagement with an Equal Number of Teeth on the First and Second Gear-Clusters. At the Front End Are Only 6 Teeth of a Full Complement of 18, 2 Teeth Being Omitted between Adjacent Teeth as Shown at the Extreme Right. The Six Teeth Engage the Teeth on the End of the Main Shaft for the Direct Drive and Those on the End of the Cup Gear for the Third-Speed

forging, which is supported in the center section of the transmission-case by a large roller-bearing. It should be noted that the sleeve-gear is mounted on a pair of roller-bearings that are eccentrically located with reference to the cup gear, the amount of offset being determined by the tooth difference and the pitch of the mating internals. For this application, a 10 to 12-pitch 27.5-deg. pressure-angle tooth was used. The offset was, therefore, 0.2 in. The somewhat blunt pressure-angle was chosen after an investigation of the tooth motion during engagement had shown that a smaller angle would result in interference. This is shown in the diagrams of Figs. 4 and 5. The pair of roller-bearings inside the cup gear serves to hold it square with the main-shaft axis and, at the same time, provides the back bearing for the main shaft, the forward end of which is conventionally mounted on an annular ball-bearing.

ANGULAR RANGE AND TIME ELEMENT OF SHIFT

A hollow metal-clutch engages teeth on the end of the cup gear and transmits the motion to the back section of the main shaft, which carries a first and a second gear-cluster, as well as the teeth on which the clutch slides. For direct drive, the clutch is moved to the rear through a neutral position to the point where its teeth engage teeth cut on the rear end of the main drive-shaft. The drawing at the extreme left and the two central drawings of Fig. 6 show a section and two end-views of the hollow clutch. At the rear end, 12 teeth 1 3/32 in. long are cut on the inside diameter. These support the sleeve and are in constant engagement with an equal number of teeth on the first and second gear-clusters. At the front end are only 6 teeth of a full complement of 18, 2 teeth being omitted between adjacent teeth. The six teeth engage the teeth on the end of the main shaft for the direct drive and those on the end of the cup gear for the third-speed, as previously stated. The two just mentioned each have 18 teeth, with a nominal face-width of 11/32 in., but only every third tooth is of this width, the two intervening teeth being cut short on the engaging ends by 7/64 in. It is evident, therefore, that there is a possible 40-deg. maximum angular-motion of point *a* of the drawing at the extreme right after the clutch tooth has just passed one of the long teeth and before it strikes the next long tooth at point *b*.

Compared with conventional spur-gear engagement, the time element for the shift is many times greater, since in that case the maximum angular-motion of the shift is limited to the pitch-line backlash plus the tooth chamfer. The shock of engagement is, of course, in proportion to the difference in velocity of the moving parts and since the shift on this transmission can be made at car-speeds where the difference is considerable, a single tooth would not be sufficient to withstand the blow; but the six large teeth on the hollow clutch have been found to be ample for carrying the impact. To prevent abrasion, the clutch teeth and those on the shaft and cup gear are hardened.

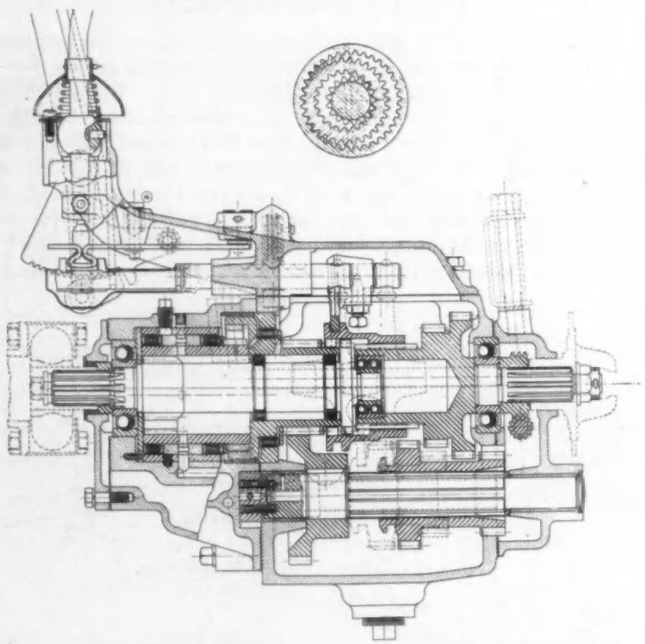


FIG. 7—TRANSVERSE SECTION OF THE TRANSMISSION

The Countershaft Has the Conventional Constant-Mesh Gear-Layout But Instead of Being Keyed to the Shaft the Low and the Second-Speed Gears Are Cut on a Sleeve Which Is a Sliding Fit on Splines and Is Moved Either Forward or to the Rear To Make the Low and the Second-Speed Shifts Respectively

COUNTERSHAFT AND REVERSE IDLER

The countershaft has the conventional constant-mesh gear-layout, as shown in Fig. 7, but, instead of being keyed to the shaft, the low and the second-speed gears are cut on a sleeve, which is a sliding fit on splines, and this sleeve is moved either forward or to the rear to make the low and the second-speed shifts respectively. The long reach from the end of the gear-shift lever to the countershaft cluster is accomplished by the use of a fork, mounted with a sliding fit on a bar assembled in the center portion of the case. The lower end of the fork engages a groove on the gear, and a pilot at its upper end projects into a hole provided in the shift rail.

The reverse idler is located on the left side of the transmission and is shifted by a fork similar to that used for low and second-speeds. It is of interest to note that the reverse idler is not in mesh except when shifted into engagement. This eliminates one source of noise in the transmission when it is operating in any of the other gear-ratios.

Shift of third and fourth-speeds is controlled by a fork attached to the center rail with its lower end engaging directly with a groove on the outer surface of the clutch.

LEVER POSITIONS

The positions of the control-lever for the different speeds are of necessity different from those for a three-speed transmission. Low-gear lever position is to the left and toward the rear. Second is directly ahead of low, and third is to the right and toward the rear. Directly ahead of third is four or direct-drive level position. The progression through the gear-ratios is in a natural

order, the only difference from the conventional three-speed locations in the forward-shift positions being that second-gear is located in the place usually occupied by the reverse gear.

To shift into reverse, the lever handle is moved to the right as far as possible and pressed down slightly. The handle can then be moved still farther to the right and, by pushing it forward, the reversing gears are moved into mesh. The feature of having a stop to prevent accidental engagement of the reverse gears allows the shifting of the other speeds with a freedom that is not attainable with the standard three-speed layout.

Lubrication

After much experimenting with scoops, troughs and scrapers for distributing oil to the parts of the internal-gear unit, it was decided to adopt a positive method by incorporating a vane-pump at the front end of the countershaft. This pump draws oil from the pocket beneath it and delivers the lubricant to the annular ring between the sleeve-gear bearings. From there the oil passes to the front of the case, lubricating the ball-bearings, then into the main case. Lubrication of the countershaft bearings is also accomplished by oil delivered from the pump to a hole in the countershaft and then to each bearing through right-angle holes. The remainder of the transmission is lubricated in the conventional manner.

TABLE 1—TRANSMISSION, AXLE AND OVER-ALL RATIOS

Speed	Transmission Tooth-Combinations	Transmission Ratios	Axle Ratios	Over-All Ratios
Reverse	21/17x35/31x27/18x21/21x29/16	3.792	3.9	14.79
First	21/17x35/31x27/18x29/16	3.792	3.9	14.79
Second	21/17x35/31x27/18x24/21	2.391	3.9	9.32
Third	21/17x35/31	1.394	3.9	5.44
Fourth	Direct	1.000	3.9	3.90

Undergear Ratio

The two pairs of internal gears at the front end of the transmission, Fig. 8, give an over-all ratio through the cluster of 21/17 x 35/31 or 1.394 to 1.000. It is thus evident that, whatever ratio at the axle is chosen for the direct drive, the drop in engine-speed from third to fourth is 28 per cent, which gives the desirable features accompanying slow engine-speed without reducing the car ability in the direct drive sufficiently to require frequent shifting from fourth to third-gear.

The transmission and over-all ratios for a passenger-car application are tabulated in Table 1. The direct-drive ratio is 3.9 at the rear axle, while those for the third, second, first-speeds and the reverse are 5.4, 9.3, 14.8, and 14.8, corresponding to transmission ratios of 1.4, 2.4, 3.8, and 3.8 in the order named. This passenger-car formerly used a 4⅞ to 1 axle-ratio.

Ability Comparison

A comparison in Table 2 shows the relative ability of the car in hill-climbing and acceleration, the ability in direct drive with the standard three-speed transmission being taken as 100 per cent. Losses through the transmission have not been deducted, with the exception of a 1.2-per cent loss through the internal gears, the assumption being that the spur-gear efficiencies in the two transmissions are equal.

Although the car with the standard three-speed gearbox has required a 4⅞ axle-ratio to give the performance considered desirable, it is interesting to note that third-gear ability with the four-speed transmission has been increased 12 per cent, while the maximum engine-speed in direct drive is still 20 per cent less than that of the car when equipped with the three-speed gearbox.

TABLE 2—COMPARATIVE ABILITY OF THREE AND FOUR-SPEED TRANSMISSIONS

	Over-All Ratio		Comparative Ability	
Speed	Standard Three-Speed	Under-geared Four-Speed	Standard Three-Speed	Under-geared Four-Speed
Reverse	20.470	14.79	4.20	3.03
First	16.180	14.79	3.32	3.03
Second	8.630	9.32	1.77	1.91
Third	Direct Drive 4.875	5.44	1.00	1.12
Fourth	None	Direct Drive 3.90	None	0.80

That the fourth gear-ratio can be applied with great advantage to truck installations is shown by the comparison, in Table 3, of the performance of four popular trucks in the 1 to 1¼-ton class, numbered from 2 to 5 inclusive, truck No. 1 having a four-speed internal underdrive transmission. This table shows conclusively the important improvement in truck performance on hills that can be realized by the use of an additional efficient gear-ratio in the transmission, allowing, at the same time, the maximum road-speed of 50 m.p.h. on the direct-drive ratio.

Undergearing and Overgearing

Right here it might be well to present the reasons for undergearing in third speed instead of overgearing in fourth. Undergearing in a four-speed transmission means that the third forward-speed is a geared ratio, the driving-end turning faster than the driven, while the fourth is the direct drive. For a given over-all ratio in fourth, it is apparent that the direct drive in this speed possesses important advantages.

The rear-axle ratio is reduced, allowing a larger drive-pinion that is correspondingly stronger and less difficult to make quiet. More important than this is the fact that, if the fourth-speed over-all-ratio is properly selected, it will give a car-ability factor that allows more than 90 per cent of normal driving to be done in the fourth-speed. Again, as the direct drive represents the maximum quietness and efficiency obtainable, it should be selected for the ratio used the major portion of the time. Also, the general wear of the transmission will be reduced, as no gears are operating under load in the direct drive.

With the long propeller-shaft commonly used, a reduction in the maximum shaft-speed would undoubtedly be welcomed by the industry, in spite of the accompanying

TABLE 3—COMPARATIVE TRUCK-PERFORMANCE

Truck No.	1	2	3	4	5
Rating	1-Ton	1¼-Ton	1-Ton	1-Ton	1-Ton
Grade Negotiable in Fourth-Speed, per cent	4.70	No Fourth-Speed	No Fourth-Speed	No Fourth-Speed	No Fourth-Speed
Grade Negotiable in Third-Speed, per cent	7.15	4.72	5.20	4.50	4.15
Superiority of Truck No. 1, per cent	...	51.00	37.00	59.00	72.00
Grade Negotiable in Second-Speed, per cent	12.15	8.52	9.47	8.20	No Second-Speed
Superiority of Truck No. 1, per cent	...	42.00	28.00	48.00	...
Grade Negotiable in First-Speed, per cent	20.35	19.45	19.35	16.85	14.55
Superiority of Truck No. 1, per cent	...	10.00	10.00	19.00	38.00
Type of Transmission Used	Four-Speed Internal Underdrive	Three-Speed Conventional	Three-Speed Conventional	Three-Speed Conventional	Two-Speed Planetary

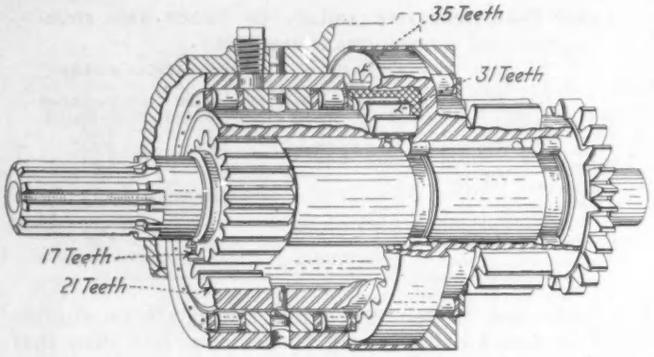


FIG. 8—SECTION THROUGH THE INTERNAL GEARS
The Two Pairs of Internal Gears at the Front End Give an Over-All Ratio through the Cluster of 21/17 x 35/31 or 1.394 to 1.000. A Vane-Pump at the Front End of the Countershaft Draws Oil from the Pocket beneath It and Delivers the Lubricant to the Annular Ring between the Sleeve-Gear Bearings. Thence the Oil Passes to the Front of the Case, Lubricates the Ball-Bearing and Returns to the Main Case

increase in operating torque. Even in truck operation, experience has demonstrated that, when the ratios are properly selected, the top ratio is the one used by far the greater part of the time, even with the loaded vehicle. Again, it should be pointed out that the direct drive represents the peak of transmission quietness. The noise, however slight, of gears in operation in third-speed will be found much less objectionable, if heard at all, when the car is moving in heavy traffic or is climbing steep grades, under which conditions the third-gear would generally be used.

GASOLINE ECONOMY

An indirect but important effect of adding a ratio to the transmission is that realized in gasoline economy. The engineering fraternity well appreciates the extravagant waste of fuel caused by operation of the automobile engine under comparatively light load most of the time. The average load-factor is greatly increased by the change in the top-gear ratio effected when a fourth-speed is added to the transmission. This is clearly shown by the results of road-tests made at the Long Island Motor Parkway of a four and a six-cylinder car equipped with a four-speed internal underdrive transmission, having the fourth-speed direct-drive connected to a 3.9 axle. The over-all third-gear ratio was 5.4. Examination of

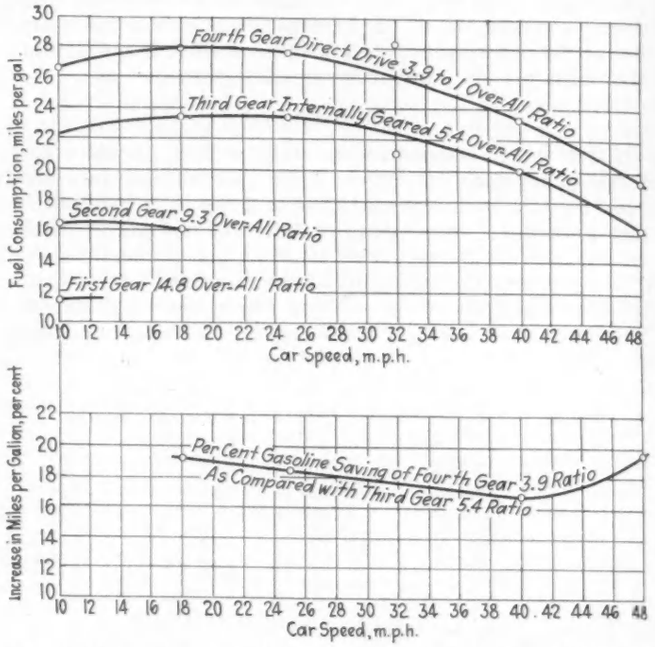

Fourth Gear Direct Drive 3.9 to 1 Over-All Ratio
Third Gear Internally Geared 5.4 Over-All Ratio
Second Gear 9.3 Over-All Ratio
First Gear 14.8 Over-All Ratio
Fuel Consumption, miles per gal.
Car Speed, m.p.h.
Per Cent Gasoline Saving of Fourth Gear 3.9 Ratio
As Compared with Third Gear 5.4 Ratio
Increase in Miles per Gallon, per cent
Car Speed, m.p.h.

FIG. 9—CURVES SHOWING RESULTS OF GASOLINE-ECONOMY TESTS OF THE FOUR-SPEED INTERNAL-UNDERDRIVE TRANSMISSION
The Upper Chart Shows the Increase in Miles per Gallon Obtained When the Final-Drive Ratio of a Four-Cylinder Engine in a Model-M Coach Is Reduced from 5.4 to 3.9; the Lower Chart, the Percentage of Increase Thus Obtained

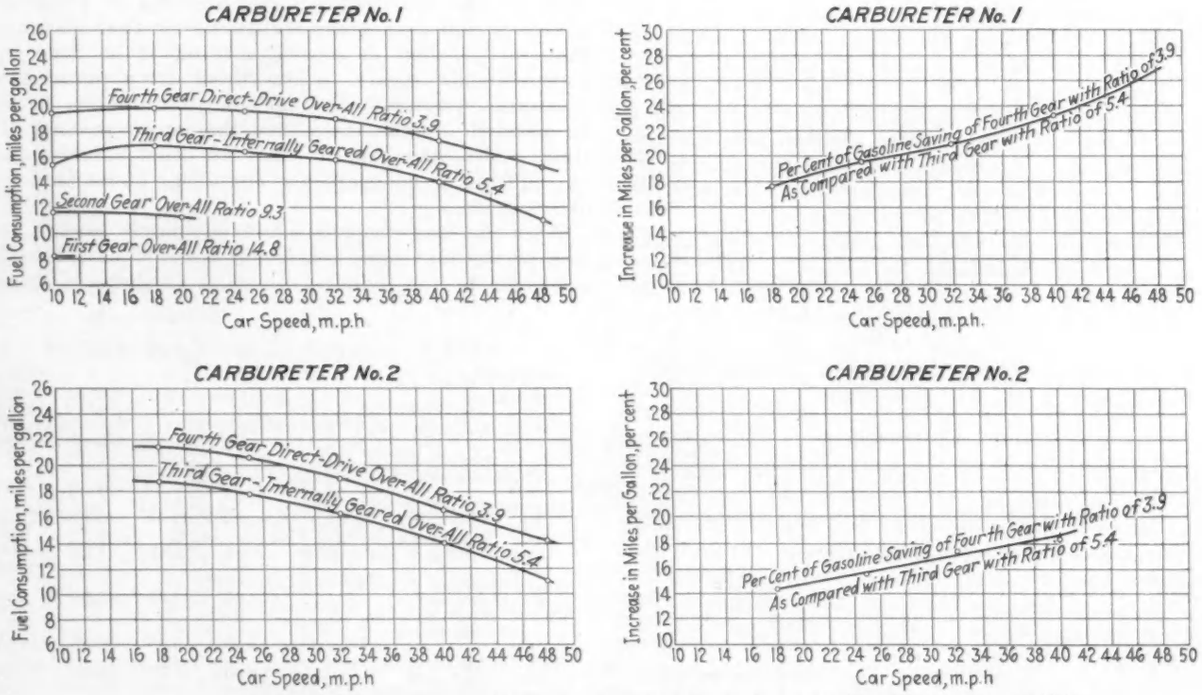

CARBURETER No. 1
Fourth Gear Direct-Drive Over-All Ratio 3.9
Third Gear - Internally Geared Over-All Ratio 5.4
Second Gear Over-All Ratio 9.3
First Gear Over-All Ratio 14.8
Fuel Consumption, miles per gallon
Car Speed, m.p.h
CARBURETER No. 1
Per Cent of Gasoline Saving of Fourth Gear with Ratio of 3.9
As Compared with Third Gear with Ratio of 5.4
Increase in Miles per Gallon, per cent
Car Speed, m.p.h.
CARBURETER No. 2
Fourth Gear Direct-Drive Over-All Ratio 3.9
Third Gear - Internally Geared Over-All Ratio 5.4
Fuel Consumption, miles per gallon
Car Speed, m.p.h
CARBURETER No. 2
Per Cent of Gasoline Saving of Fourth Gear with Ratio of 3.9
As Compared with Third Gear with Ratio of 5.4
Increase in Miles per Gallon, per cent
Car Speed, m.p.h

FIG. 10—FURTHER GASOLINE-ECONOMY TESTS OF THE FOUR-SPEED INTERNAL-UNDERDRIVE TRANSMISSION
In the Upper Views Are Shown the Results Obtained on a Model-R Landau Sedan Equipped with a Six-Cylinder Engine, That at the Left Being with a No. 1 Carbureter, That at the Right, with a No. 2 Carbureter. In the Lower Views, the Graphs Show the Corresponding Percentages of Increase

the curves shown in Figs. 9 and 10 indicates what can reasonably be expected in the way of gasoline saving when the final-drive ratio is reduced from 5.4 to 3.9. The upper chart of Fig. 9 shows the car miles per gallon in first, second, third and fourth speeds and that a saving of 17.8 per cent at 30 m.p.h. is attained on the four-cylinder car. On the six-cylinder car with Nos. 1 and 2 carbureters, shown in the upper views in Fig. 10, the saving at 30 m.p.h. is 20.5 and 16.7 per cent respectively.

It will be observed that the gasoline economy on the three different tests showed a minimum saving of 14.4 per cent at 18 m.p.h. on the six-cylinder car with No. 2 carbureter, upper right view of Fig. 10, while at the same speed the car, when equipped with No. 1 carbureter, upper left view, showed an improvement in gasoline mileage, in the fourth speed as compared with the third, of 17.6 per cent. The gasoline saving on the four-cylinder car, Fig. 9, was the minimum of 16.8 per cent at about 40 m.p.h. A glance at the maximum percentage savings indicates that, at certain driving-speeds, the possible improvement in economy is somewhat greater. The percentages run from 18.4 per cent maximum on the six-cylinder car with No. 2 carbureter, upper right view of Fig. 10, at 40 m.p.h. to 26.8 per cent estimated maximum, at 48 m.p.h. on the six-cylinder car with No. 1 carbureter, upper left view of Fig. 10. The actual measured percentage at this speed was 38.4 per cent, but imperfect carburetion or valve action is probably responsible for this somewhat unreasonable result.

At first thought it might be expected that the maximum percentage gain would not fall at a high car-speed, but a study of the mileage curves shows why it actually does. The saving in miles per gallon is fairly constant over the entire speed-range, whereas, the mileage of the third-gear, on which the percentage is based, falls as the speed increases, with the result that the percentage saving becomes correspondingly larger. The importance of the correct mixing of the fuel and the air in the carbureter is evidenced by the difference in the nature of the curves of the six-cylinder engine equipped with Nos. 1 and 2 carbureters. The percentage savings are markedly different in the two tests and, since no change was made on the car other than substitution of carbureters, it is apparent that the characteristics of the two instruments were distinctly different. The difference would undoubtedly have been reduced by adjusting the two carbureters to give exactly the same mileage at one particular speed; but this was not attempted.

Internal-Gear Efficiency

To learn something of the effectiveness of internal gearing as a means of speed reduction through a transmission, efficiency tests were conducted on a Twin-High unit of a type originally designed for application to Ford cars. The results of these tests indicate a power loss through the internal unit due to gear losses of only 2 per cent under full load. An amount as small as 2 per cent requires more accurate laboratory work than is ordinarily necessary. It was only after considerable preliminary study and calibration of the test apparatus that the power output was found to be actually less than the input. Humorously enough, the opposite report was made by a member of the laboratory personnel on one of the trial runs. The efficiency of internal gearing was also evidenced by a heat-rise test of the Twin-High unit operating in third-gear, as compared with a standard transmission in second-gear. Indefinite operation in third-gear was possible on an unventilated torque-stand, whereas the conventional transmission could not be run

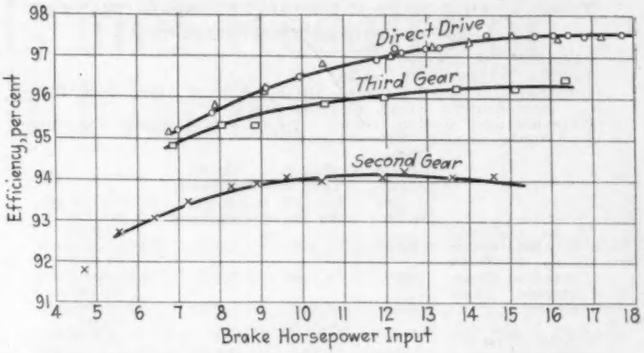


Fig. 11—Comparative Efficiency Curves of the Four-Speed Internal-Underdrive Transmission and of Spur-Gearing

The Speed of the Driving End Was Constant at 1500 R.P.M. The Power Loss through the Internal Gears Is Shown To Be Less Than 1.5 Per Cent. It Was Surprising To Find That the Total Power-Loss through the Double Set of Gears Was as Low as 3.75 Per Cent, When It Is Considered That This Figure Also Includes Losses in the Bearings, Speedometer Drive and Oil-Pump, and That Resulting from Work Done on the Oil

long continuously in second-gear before dangerous oil-temperatures were reached. On account of the difference in ratio of the two units tested and of other differences, such as the shape and the exposed radiation-surface, the heat-rise results are only indirectly comparable. Nevertheless, the difference in the rise of the oil temperature was so marked that there is no question as to the superior efficiency of internal gearing as compared with spur-gearing. Later, efficiency tests were made of the Twin-High transmission mentioned in this paper that confirm the results of the original tests by showing a power loss through the internal gears of less than 1.5 per cent, as illustrated by the curves of Fig. 11. The latter transmission is now being used in production on a 1-ton truck, and experimentally on four and six-cylinder engines for passenger-cars. It is surprising to find that the total power-loss is as low as 3.75 per cent through a double set of gears, considering that this figure also includes the losses in the bearings, speedometer drive and oil-pump, and that resulting from work done on the oil. In all the above-mentioned efficiency-tests a good grade of medium engine-oil was used as a lubricant.

The lost load was measured on the small scales, the torques of the driving and of the driven dynamometers being balanced through the heavy walking-beam overhead. This is more clearly illustrated with the diagrammatic layout of Fig. 12.

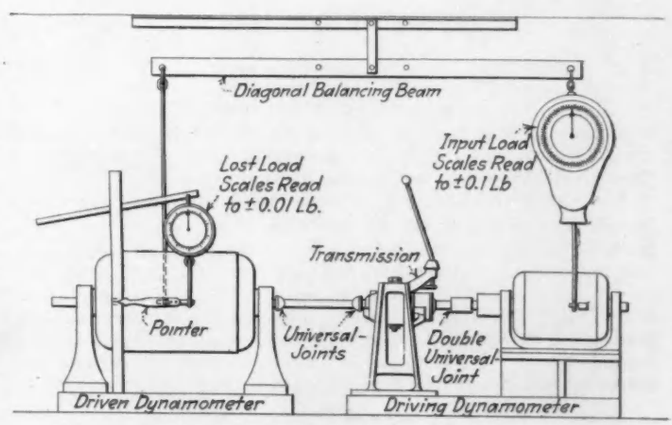


Fig. 12—Diagrammatic-Layout of Testing Apparatus

The Lost Load Was Measured on the Small Scales, the Torques of the Driving and of the Driven Dynamometers Being Balanced through the Heavy Walking-Beam Overhead

TABLE 4—FOUR-SPEED INTERNAL UNDERDRIVE TRANSMISSION GEAR-TEETH CHARACTERISTICS

Assembly No. 18473
Engine Torque, 1200 Lb-In.
Internal and Mating Gears, 10 to 12-Pitch; 27½-Deg. Pressure-Angle; 2-Deg. Friction-Angle
External and Mating Gears, 7 to 9-Pitch; 20-Deg. Pressure-Angle; 5-Deg. Friction-Angle

	Tangential Pressure, Lb. per Sq. In.	Tooth Pressure, Lb. per Sq. In.	Tooth Pressure, Lb. per Sq. In.	Tooth Stress, Lb. per Sq. In.
21 to 17-Tooth Internal Gears	1,413	1,625	1,625	32,800 External Gear
35 to 31-Tooth Internal Gears	958	1,100	2,075	26,200 External Gear
Constant - Mesh Gears	1,305	1,440	2,090	29,700 Countershaft Gear
Second - Speed Gears	1,675	1,850	3,290	49,600 Countershaft Gear 43,600 Cluster Gear
First - Speed Gears	2,200	2,430	4,320	59,250 Countershaft Gear 60,600 Cluster Gear
21 - Tooth Reverse Gear	1,675	1,850	3,290	40,600
16 - Tooth Reverse Gear	2,200	2,430	4,320	59,250

Quietness

Internal gearing was originally chosen for this application because of its known superiority over spur-gearing for quiet operation. The gradual approach and recession of the engaging teeth is undoubtedly in the main responsible for their lack of appreciable noise. Also, the form of the contacting teeth, Figs. 4 and 5, which have mating-surfaces with curves much less divergent than those of spur-gear teeth, may assist in quieting their operation. The cushioning effect of the oil retained on the internal teeth by centrifugal force contributes to the diminished noises of the gearing. Certainly there is a degree of quietness in this arrangement of internal gearing that cannot be easily attained in commercial spur-gearing.

In production transmissions, the internal gearing varies in quietness. Some show no noise whatever in third gear-combination under load except to a trained ear, while others have a not unpleasant murmur that can be heard in an automobile operating where there is little other noise. Hence, a third gear-combination, practically as quiet as the direct drive, is actually realized in some cases and is so nearly realized in the average transmission that the performance in the internal-geared third-combination is agreeably quiet to the occupants of the car and is generally only slightly more audible than the direct-drive fourth-combination, although the difference in engine noise due to the great difference in engine-speed is very apparent.

The internal-gear cluster is fortunately not a large assembly and, therefore, does not add greatly to the bulk of a transmission. The reason it can be small is that the shape of the internal-gear tooth is exceptionally broad at the base, especially with the large pressure-angle used. The small difference between the number of teeth on the pinion and on its mating internal-gear makes it appear that several teeth are always in mesh. A study of the engagement discloses that this is not literally true, but it is not improbable that the space occupied by the oil-film and the deflection of the most heavily loaded tooth does allow a certain portion of its load to be transferred to the next tooth. A partial analysis of the tooth loading is given in Table 4.

Conclusion

In consequence of the great possibilities for improvement in all-round car-performance attainable by the use of a suitable four-speed transmission, it appears that a more or less general tendency in this direction may be expected within the next 2 or 3 years. Unquestionably, a number of successful methods will be evolved by which an additional useful-ratio between the engine and rear wheels can be obtained. Without doubt, the most attractive feature of the additional ratio is the gasoline economy effected, and, if no other advantage existed, this saving alone would justify the expenditure of all the time and effort that is required to develop a successful product.

AUTOMOTIVE RESEARCH

(*Concluded from p.* 196)

a color year in our industry as well as in others, corelation existing, even if only in the subconscious. Green is most popular, with blue, gray and maroon following. Sport models in black and seagull gray or polished aluminum strike a new note. On the subject of color, jet-black tires furnished by one maker should be mentioned.

The extended roof with an integral visor has been challenged by the sharp, cutoff roof with cadet cap visor. Even without visor, the new cutoff effect is appealing. Phaetons and runabouts, with prominent beadings and a door panel insert of bright color, are more numerous. The conventional windshield side-arm is being replaced by a corner post simulating closed-car design. This seems to be the transition keynote to the convertible sedan and coupe, which are ingenuous in construction and appearance.

Foreign Designs

Foreign practice is always of interest. Some of its trends are noted below.

European engineers are incorporating American characteristics into their product. A reformation has set in. Among prominent developments is the revised form of the two-piston per cylinder engine, in the form of a two-cycle, double-crankshaft unit, for racing and aircraft. The chief virtue is the ability to decrease the individual reciprocating mass moments, together with perfect balance. Duralumin connecting-rods are common. The centrifugal type of oil-cleaner is being used. Timing-gear trains adjacent to the flywheel, where they are immune from the destructive effects of crankshaft torsional vibration, are used in a number of instances due to added body-room available with this construction. The pendulum torque-converter has been shown in commercial form. The individual-clutch principle has been revived in a planetary set with electro-magnetic control. Individual front-wheel steering is used to combat shimmy. Spring axles are used, as well as wheel mountings on the end of a radius-rod, in one case incorporating an internal-gear drive. English designers show various methods of mounting bodies to prevent chassis-frame weave and vibration from reaching the body.

Purposes, Methods and Results of Chromium Plating

By W. N. PHILLIPS[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS

ABSTRACT

CHROMIUM plating for decorative effect has been used for considerably more than a year on the Oldsmobile radiator and bumper bars and is now being extended to other cars built by the General Motors Corporation. The application of chromium to gages and burnishing-tools by the Buick Motor Car Co. to prolong their life has been very successful. In one instance about 1,000,000 small spindles were chromium plated instead of being carburized or otherwise hardened and were found to resist wear better. These spindles carry a very low load per square inch but are subject to extreme conditions of wear. Piston-pins plated with chromium are now in production and the Corporation expects that this use of chromium will be extended considerably.

The method followed to produce a permanent decorative effect on exposed parts is first to produce as smooth a surface as possible by plating with copper and nickel and buffing to a high finish, after which a light coating of chromium is applied. The cost is comparatively low considering the protection afforded. A steel base plated with 0.001 in. of nickel and then chromium plated will withstand from 80 to 100 hr. of salt-spray test, compared with 15 hr. when the same thickness of nickel-plating is not protected by chromium. The surface does not tarnish under exposure to the humid salt air in Florida and southern Texas.

Chromium trioxide, which contains about 50 per cent of chromium metal, is the chief material used in chromium plating, which is not a very difficult process. The trioxide costs about 35 cents per lb. at present but the price probably will decline as its use increases. High-current densities, with very short immersions in the baths, are used for plating radiator shells and bumper bars. Hardness of the deposit can be controlled, but it is believed that the highest luster can be obtained by depositing the chromium in its bright modification.

Plug, thread and other gages protected by one plating last from 2 to 25 times as long as the best steel-gages. They are ground about 0.005 in. undersize and then brought up to size by plating. When finally worn, they can be deplated and a new coating applied. Burnishing-tools coated with chromium have been very successful because of the low coefficient of friction between this metal and others. Files for cutting soft metals can be plated with great advantage, as the soft metals do not clog the files. The plating of edged tools for cutting hard materials is not recommended, however, as the chromium has a tendency to fracture and roughen the work.

No instrument for measuring the hardness of chromium has been developed, but some of the soft modifications of chromium plate have been measured by studies of the microstructure.

THE subject of chromium plating is no longer new. Dr. Colin G. Fink presented an excellent paper[2] on this subject before the Detroit Section recently. Special experience with some phases of the process, re-

[1] Factory production engineering section, General Motors Corporation, Detroit.

[2] See THE JOURNAL, January, 1927, p. 157.

FIG. 1—EQUIPMENT FOR NICKEL-PLATING RADIATOR SHELLS PRIOR TO CHROMIUM PLATING
This Installation at the Olds Motor Works Plant Consists of One Steel Conveyor-Tank, Which Is Used for the Copper-Cyanide Solution, and Two Nickel-Plating Tanks with the Necessary Cleaning Baths in Front of Them

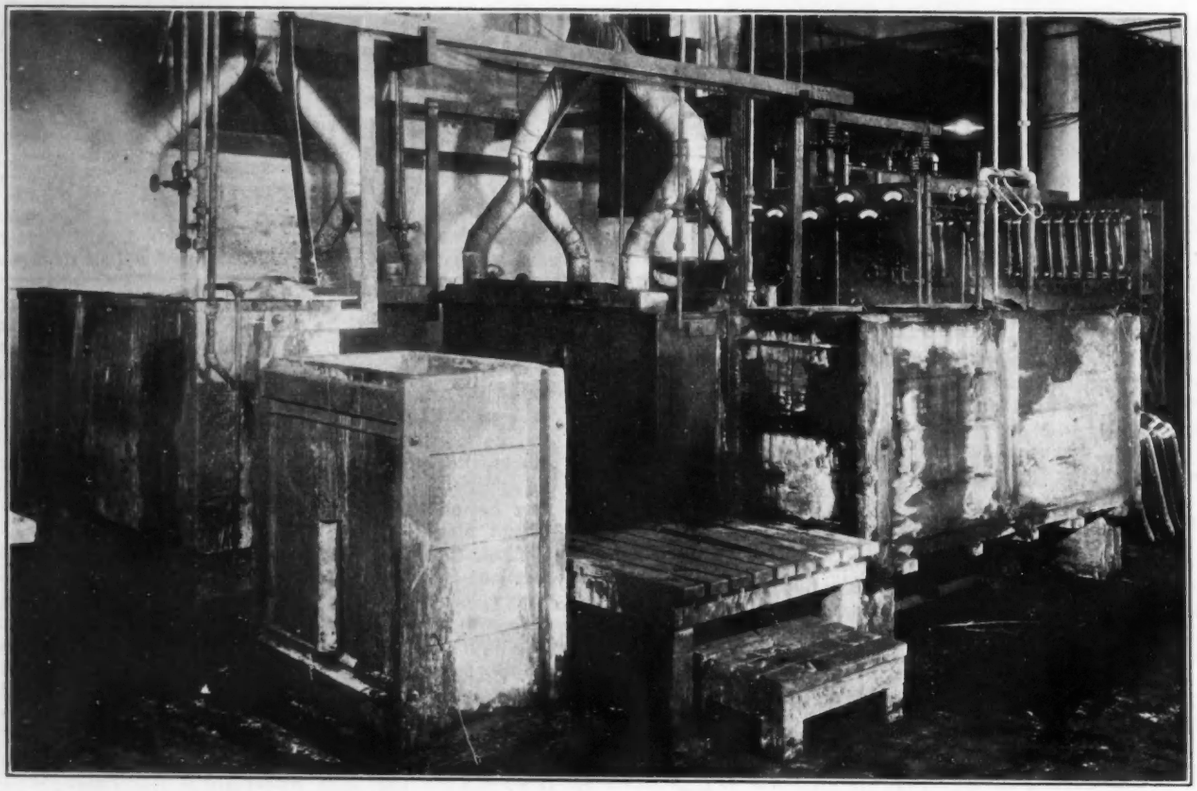


FIG. 2—INSTALLATION OF CHROMIUM-PLATING EQUIPMENT
Here the Radiator Shells Are Plated After They Have Been Nickeled and Buffed. Many Thousands of Pieces Have Been Chromium Plated, Including Not Only Radiator Shells but Almost Every Exposed Part of Eight Oldsmobile Chassis That Have Been Sent Practically All Over the World for Exhibition at Shows

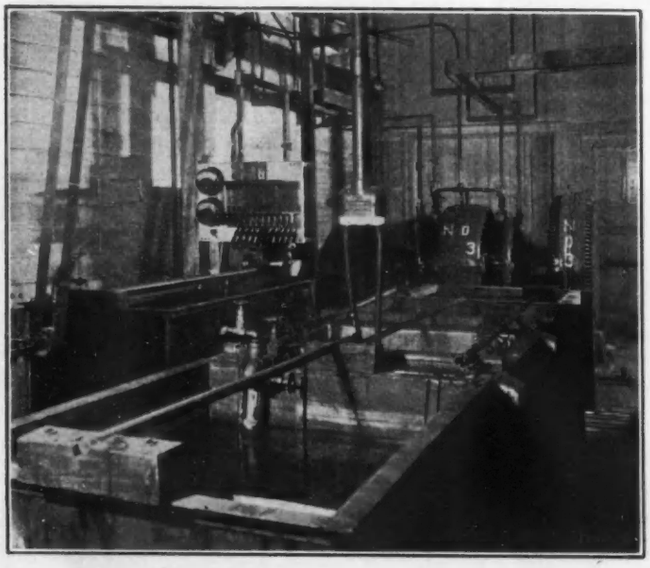


FIG. 3—PART OF THE EQUIPMENT FOR CHROMIUM PLATING RADIATOR SHELLS AND OTHER PARTS AT THE OAKLAND MOTOR CAR CO. PLANT

lating particularly to the automotive industry, has been had by us in the General Motors Corporation.

The application of chromium has two main purposes: (*a*) to produce a permanent decorative effect and (*b*) to prolong the life of mechanical parts that are subjected to unusual conditions of wear or temperature.

Our application for decorative effect has been used for considerably more than 1 year on the Oldsmobile radiator and on the bumper bars. Its use is now being extended

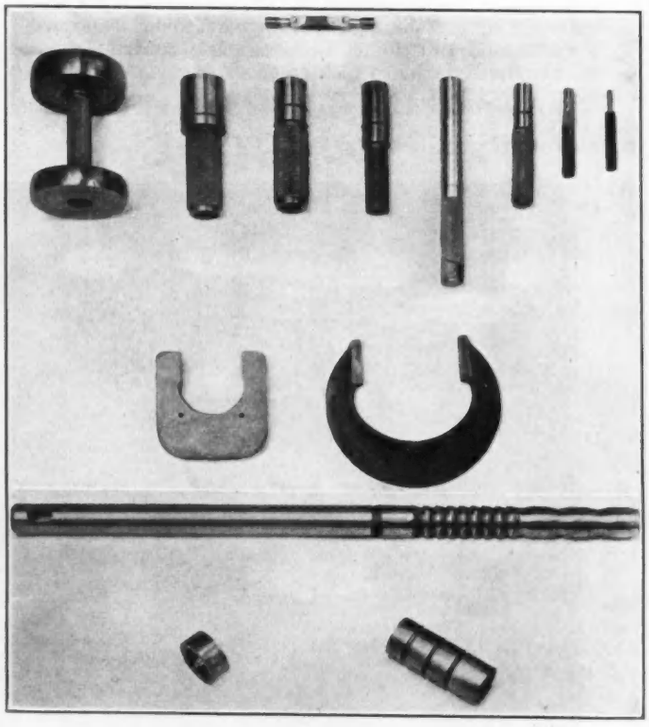


FIG. 4—CHROMIUM-PLATED GAGES AND TOOLS
The Life of Plug and Snap-Gages, Broaches and Burnishing and Other Tools Is Greatly Prolonged by Plating with Chromium. The Gages Are Ground about 0.005 In. Undersize and Then Plated To Bring Them Up to Exact Size, or to Oversize and Then Ground Down to Exact Size. When Wear Has Occurred, They Are Deplated and Plated Again to Size. This Method Gives Them Indefinite Life

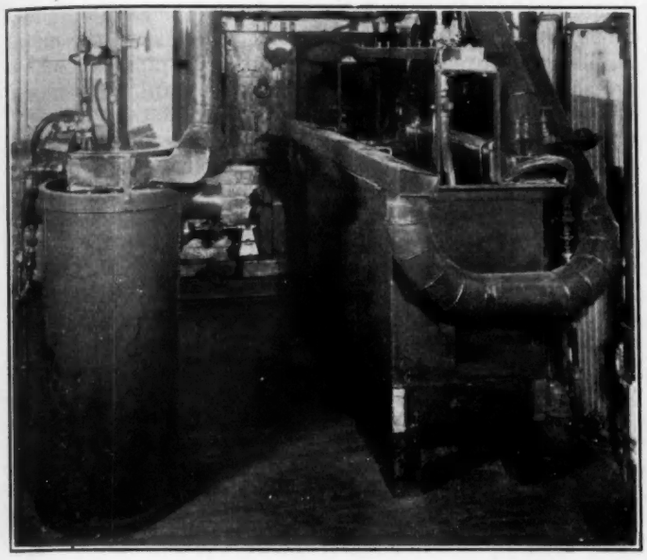


FIG. 5—SMALL EQUIPMENT FOR PLATING TOOLS AND GAGES
This Is Part of the Installation at the Olds Motor Works

to other cars built by the Corporation. The method followed is to produce as smooth a surface as possible by plating the steel parts with copper and nickel, using the equipment shown in Fig. 1, and then buffing them to a high finish, after which a light coating of chromium is applied with the equipment illustrated in Figs. 2 and 3. This method produces a lustrous finish and has several advantages. The first of these is the comparatively low cost considering the protection that the finish provides. We have found it somewhat difficult to produce nickel-plating less than 0.001 in. thick that will withstand a salt-spray test for 15 hr., but a steel base nickel-plated with this thickness of nickel and then chromium plated will withstand 80 to 100 hr. of the test. Two radiator shells that were exhibited in connection with a paper on chromium delivered at a meeting of the American Society for Steel Treating about 1 month ago have been exposed

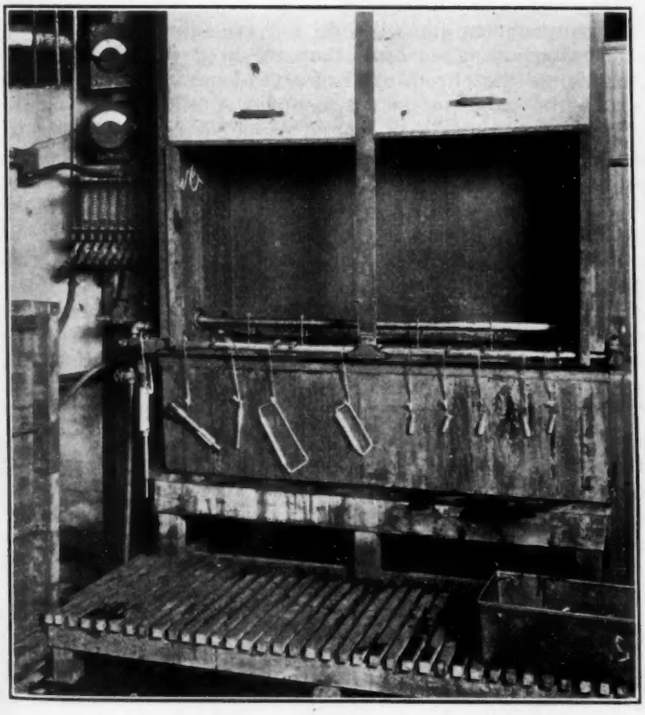


FIG. 6—METHOD OF SUSPENDING TOOLS AND GAGES FOR PLATING
The Racking and Wiring Are Very Similar to Methods Used in Any Kind of Electroplating. The Process of Chromium Plating Is Not Really Difficult. The Equipment Shown Is Part of That Installed at the Plant of the Buick Motor Co.

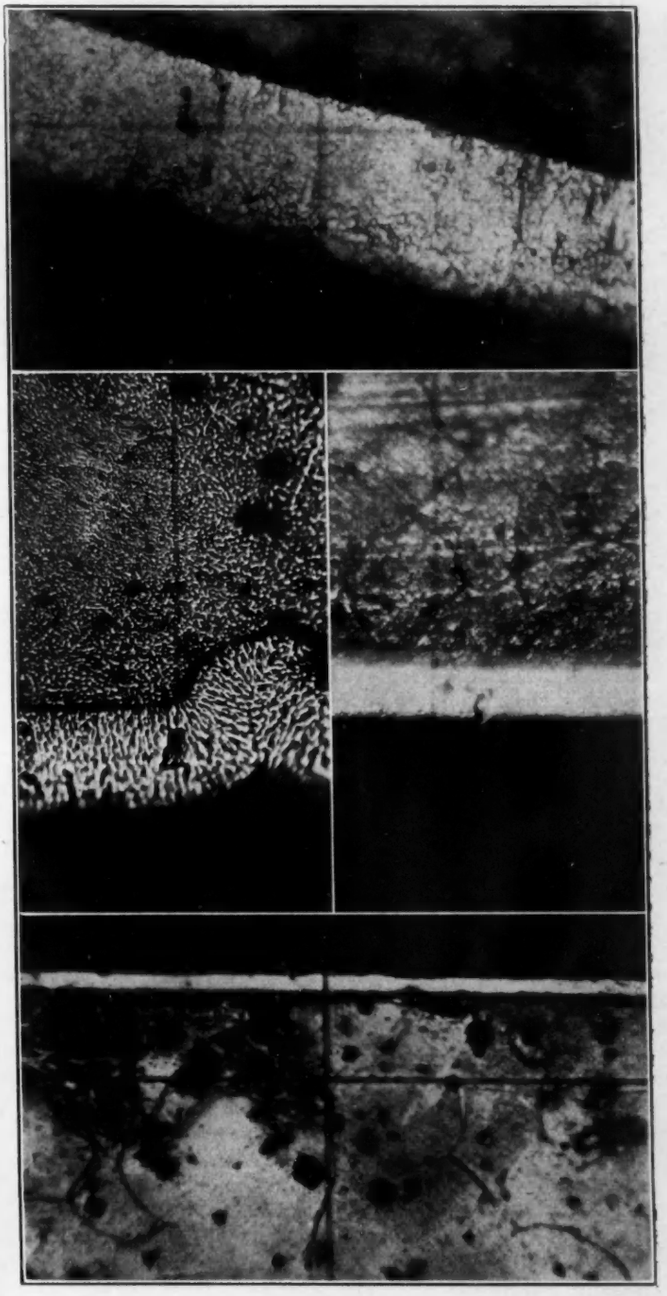


FIG. 7—PHOTOMICROGRAPHS OF CHROMIUM PLATING
The View at the Top Is a Cross-Section of 2-Hr. Plate on Cold-Rolled Steel at 30 Deg. Cent. (86 Deg. Fahr.) Etched in 10 Per Cent of Hydrochloric Acid in Water for 30 Sec. and Magnified Approximately 1500 Times. The Left Center View Shows the Cross-Section of a 2-Hr. Chromium Plate on Cold-Rolled Steel at 50 Deg. Cent. (122 Deg. Fahr.) Etched as Before and Magnified Approximately 1270 Times. The Difference in Structure of the Two Samples Explains Why One Deposit Is Harder than the Other. The View at the Right Center Is of the Structure of Plate Produced in 2 Hr. at 50 Deg. Cent. Etched with Dilute Picric Acid in Alcohol and Magnified 425 Times. This Method Failed To Show the Structure as Well as the Other Treatments. The Bottom View Shows the Cross-Section of Plate on Small Production-Parts, Etched in Nitric Acid and Magnified About 1450 Times. The Uniformity and Continuity of the Plate Are Significant. The Plating on the Four Samples Was Done at the Plant of the A C Spark Plug Co., in Flint, Mich.

to the weather on our roof since that time. One is nickel-plated only and the other has been given the chromium treatment.

Aside from giving protection against rust, the chromium surface is infinitely superior to a nickel surface, even if pure nickel sheet were used, as the chromium will not tarnish under usual conditions of exposure, including exposure to salt air and high humidities such as are encountered in Florida and southern Texas.

Chromium Plating Not Too Expensive

Chromium plating is not excessively costly if it is done in accordance with the outline given. It is true that chromium plating is covered by many patents, but the companies that own these patents are willing to issue licenses for the use of their processes.

The chief material used in the process is chromium trioxide, which contains about 50 per cent of chromium metal and can be purchased at about 35 cents per lb., with the probability that as its use increases the price will decline. The reason for this is that until chromium plating began to come into common use no great volume of chromium trioxide was used, consequently it was made in small batches and shipped in glass bottles; but a ruling of the Interstate Commerce Commission now permits its shipment in non-returnable steel drums very similar to those used for shipping caustic soda.

In applying chromium, high-current densities are used, with very short immersions in the plating baths. This applies mainly to articles such as radiator shells and bumper bars.

Hardness of chromium is a controllable property. The metal can be deposited and then buffed readily but it is our belief that the greatest luster can be obtained by depositing the chromium in its bright modification.

Dr. Fink gave as one of the reasons for the high protective-value of chromium the fact that it is difficult to wet the surface of this metal and demonstrated this with a spoon containing water. However, we do not believe that chromium, by itself, is as good a rust-preventive coating for steel and iron as the combination of a chromium surface over other metals. It is extremely difficult to plate other metals over chromium unless certain precautions are taken, but the value of such procedure is not particularly great in the decorative use of the metal.

When light coatings of chromium are applied over nickel, or over copper and nickel, in accordance with the method described, the resultant coat, although extremely hard, will not withstand a file-test. However, it will resist exposure and wear on car parts for a long time under ordinary use; we cannot say how long because our cars with chromium plating have not been out for a sufficient length of time to wear out the chromium. Regular production was started at the Olds Motor Works in September, 1925, and the plating on many cars produced experimentally more than 1 year before that is still in splendid condition.

The other use of chromium, which may, in time, become more important to the automotive and other industries, is the mechanical application. Our use of the metal on plug and thread-gages and the like, examples of which are shown in Fig. 4, has been very successful. The gages are ground about 0.005 in. undersize and then brought up to size with chromium by plating an excess of chromium which is later ground off to size, or by plating the gages exactly to size. When the gage has finally worn down, it is deplated and a new coating of chromium is applied. The equipment for this work is illustrated in Fig. 5 and the method of suspending the articles is shown in Fig. 6. Thus it is possible to use the same gage for an indefinite period. Control of the hardness is of particular importance in this work. We have been able to produce gages that would last from 2 to 25 times as long with one plating as the best steel gages.

Owing to the low coefficient of friction between chromium and other metals, we have been able to apply chromium to burnishing-tools with considerable success. The suggestion has been made that chromium be applied to dies for drawing, particularly on non-ferrous metals. Files used for cutting soft metals can be plated with chromium to great advantage, as the metals do not clog the files as they do untreated files.

Hardness Studied by Photomicrography

How hard is chromium? is often asked. We do not know exactly, because we have not developed an instrument for measuring its hardness. By studies of the microstructure of the metal we have been able to measure some of the soft modifications of chromium plate, and we find them to be considerably harder than our hardest steels. Examples of the structure of the chromium plate are reproduced in Fig. 7.

It is necessary to back-up chromium plating with hard metal if the article plated is to be put to hard usage; that is, if it is to be subjected to great impact the steel part should be carburized, or at least cyanided, before applying chromium. We do not recommend the use of chromium on edged tools that are used to cut hard materials, as the chromium has a tendency to fracture and cause the work to be roughened. A glass-cutter made from sections of ¼-in. round copper-wire filed down to an edge and then chromium plated with about 0.005 in. of chromium was exhibited at the meeting of the American Society for Steel Treating and does very creditable work.

What applications of chromium may be made to the bearing-surfaces of an automobile, either to the spindles or to the bearing-surfaces themselves, has not been determined. We have, however, in one instance, used about 1,000,000 small spindles that were chromium plated instead of being carburized or hardened by other means. These spindles carry a very low load per square inch but are subjected to extreme conditions of wear and we have found that they resist wear better than carburized spindles did. Chromium-plated piston-pins are now in production in a small way and we expect that this use of chromium will be extended considerably.

The Training of Future Executives

By JOHN YOUNGER[1] CLEVELAND SECTION PAPER

THE discussion following the presentation of this paper at the April, 1926, meeting of the Cleveland Section was entirely oral, being constituted of the remarks made by the various members from the floor. In accordance with the usual practice, a copy of the complete report was sent to the author for such replies as he cared to make to the points raised in the discussion and each speaker received an edited transcript of his remarks for correction before publication.

For the convenience of the members an abstract precedes the discussion so that those who desire to gain some idea of the subjects covered without referring to the May, 1926, issue of THE JOURNAL, in which the paper was printed, can do so with the minimum effort.

ABSTRACT

AFTER citing the highly competitive conditions in the automotive industry, the development of new metals and of improved time and labor-saving processes and methods, comment is made that direction in the use of these modern materials and production methods calls for intelligence of a high order. Such intelligence must be trained, however, and the basis of the training is the accumulated experience of years. While the final practical training must be given in the manufacturing establishment, the mind of the young man who expects to become an executive should be prepared by preliminary training to absorb knowledge rapidly so that promotion may be reasonably fast.

Universities and colleges provide varied courses for this preliminary training, in which the students are taught how to learn. Some of the larger electrical companies make a practice of influencing the courses, of pointing out the opportunities for advancement afforded in their organizations and of drawing the better qualified graduates into their employment. They also maintain training courses for a year in which the graduates become adjusted to the industrial conditions under which their future work will be carried on and acquainted with the policies and methods of the company.

While the automotive industry is now the largest in the Country and offers great possibilities to young men, it is doing practically nothing along these lines. Suggestion is made that the Society and the National Automobile Chamber of Commerce should appoint educational committees and, by maintaining contact with the educational institutions, assure that the teaching shall represent modern practices. The Society now has a means of contact through its Student Group plan. Students can have outside contacts, through THE JOURNAL and through speakers provided by the Society at Student Group meetings to acquaint them with the affairs and problems of the industry. The National Automobile Chamber of Commerce might advertise cooperatively the great opportunities offered to young men by the industry, or individual companies could present the advantages afforded by their own organizations. They could also institute training systems for those who enter their service. Although the industry is still young, it is not too early to begin to think of the future.

THE DISCUSSION

CHAIRMAN T. V. BUCKWALTER[2]:—The system of taking young men from colleges and preparing them for their work as future executives, I believe, was started by the Pennsylvania Railroad as early as by any company. I had many years of observation of the operation of that system, which was, I think, considerably different from the methods of the Westinghouse and General Electric companies and not so well adapted to its industry as theirs is. The Pennsylvania method was to employ a number of graduates as apprentices who served a fixed number of months in each of the departments and, after a course of about 4 years, were advanced to minor executive positions, with the understanding that they would work their way up gradually.

That system possessed two weaknesses, I think. The principal one was that these apprentices would have fixed in their minds the idea that, regardless of how much or how little work they did and whether or not they fitted themselves for it, an executive job was waiting for them; and they seemed to have enough influence to make that policy effective. The second great drawback was the influence of this on the 200,000 other employes of the railroad, some of whom may have been just as ambitious as the special apprentices. I cannot help but think that among these 200,000 men there would be more latent ability and better executive timber to be brought to the front than in, say, 200 special apprentices. This special-apprenticeship system deadened the ambition of the other 200,000 men, who saw younger men and men whom they often recognized were not so well fitted as themselves for executive positions, moved to the front.

That system was continued with very little change for a long period. The Pennsylvania Railroad grew into a strong position during normal times, and within the last few months one of those special apprentices was advanced to the presidency of the company. General Atterbury was an apprentice and was the first special apprentice to attain to the presidency. However, during the World War a tremendous opening-up of other opportunities occurred and literally thousands of highly technically trained men left the Pennsylvania system because of dissatisfaction with this apprenticeship system. Failure of the railroad to perform its functions as efficiently during the war as it had performed them previously and has performed them since was due more than anything else to the desertion of trained foremen, assistant foremen, engineers, and all kinds of skilled minor executives below the position of master mechanic.

I am inclined to think that the special-apprenticeship system is not so closely adhered to now as before the War. Looking over the promotions made during the last few years, I note the names of a number of practical men who came up through the ranks or entered the employ of the Company from colleges without going through the special-apprenticeship course, so I infer that the old mistaken practice of advancing a man regardless of his fitness has been abandoned to some extent.

Except for those two weaknesses, I think the policy of selecting prospective executives from the colleges and training them in an industrial organization is to be com-

[1] M.S.A.E.—Publisher and editor, *Automotive Abstracts;* professor of industrial engineering, Ohio State University, Columbus, Ohio.

[2] M.S.A.E.—Vice-president, Timken Roller Bearing Co., Canton, Ohio.

mended. I am highly in favor of it, with this reservation, that the young men taken into the organization and given a chance to work should be handled much as some swimming instructors treat their pupils; that is, throw them in the water and let them swim. Letting them sink or swim is an excellent policy; give them an opportunity but make them feel that they must work out their own salvation. If they are inclined to "soldier on the job," it is best for the company to throw them out.

Training That Colleges Can Give

C. A. Norman[3]:—Mr. Younger, I assume, has in mind mainly the training of executives by our colleges. It is of great importance to point out what the colleges may be in a position to do, because very likely the potentialities of the colleges along this line have not always been fully appreciated by the automotive industry. Until recently at least, the majority of executives in the industry were not college-trained men, yet they have accomplished wonders. To place a mechanism as complicated and as inherently costly as an automobile within the reach of the average man in a nation of more than 100,000,000 people is a marvel of achievement. Automotive executives have attacked this problem in two ways: (*a*) by quantity-production methods of the greatest ingenuity and on an unheard-of scale so as to cheapen the product and (*b*) in part at least by trying to keep up wages so as to increase the buying power of the working masses.

As regards the methods under item (*a*), I doubt if the automotive executive could learn much from the college man; in fact, the bringing of Mr. Younger to Ohio State University was due largely, I think, to a desire that he teach to college students the automotive methods as already developed. On the other hand, I hope that the college may develop in future executives a wider and keener understanding of what can be done under item (*b*). The practical man, as a rule, is not much given to discussing generalities. Unless he has been a great reader and is a born thinker his horizon may be bounded to some extent by his own experiences. If one sells merchandise to a whole nation, the whole nation's reactions should dawn on him in time, yet short-cuts to these reactions exist and are taught in colleges. They are called economics, business geography, social psychology, and so on. If the business of those who teach these subjects will increasingly be to teach them to future industrial executives, I am sure they can increasingly make their teaching fit the needs of these executives and thus shorten the period of their development.

Other ways also exist in which the college may be helpful. As Mr. Younger has pointed out, engineering progress is becoming increasingly a matter of painstaking research; it is the business of the colleges to impart the fundamental methods and the scientific principles underlying such research. Even if the future executives are not to do any research work themselves, they should have an adequate idea of the necessary conditions for the successful carrying out of research, and such a knowledge can most easily be imparted by the colleges.

A difficulty in the past has been a lack of knowledge on the part of colleges of what sort of training would be best suited to produce competent industrial leaders and, conversely, a lack of knowledge on the part of industrial leaders of how to use effectively the sort of training that the colleges could give. It has become increasingly clear that the college has given the average engineer an inadequate understanding of human beings. On the other hand, the average engineering executive has had no idea that the colleges could give anything of value toward the proper understanding of human beings. Yet the college curricula embrace courses that give material which is just as fundamental for this understanding as mathematics and physics are for the understanding of the strength of materials. Such courses are physiology, factory sanitation and hygiene, much preventive medicine and preventive psychiatry, some phases of psychology, and the like. I do not include such things as sociology and economics, which are already being taught to some extent to engineering or business executives, perhaps at times in a too specialized way. The colleges should give those fundamentals that practical experience in industry after graduation is not likely to give.

I think Mr. Younger is to be congratulated upon the way in which he has already been able to take stock of what the college can offer and the way in which he has introduced some courses in the fundamental human sciences in his industrial-engineering curriculum.

Natural Leadership Is a Prerequisite

Franklin T. Jones[4]:—The technically trained man has an important place in the industry. The engineer must be technically trained and certain financial executives must be technically, or college, trained, because that amount of training represents the minimum educational requirement. When apprentices are taken into the shop they are selected for further training and are picked, not alone because they have had a college education but also because they have characteristics upon which future training can be based. These characteristics cannot be gained solely through schooling.

A real executive can handle men and can enlist cooperation. Through those two capabilities and some others he is able to accomplish results. Only when a man can get results is he an executive. A young man cannot be sent to college or to any school, unless it is the school of experience, with assurance that he will come out able to handle men successfully and enlist the cooperation that will enable him to accomplish desired results. I believe the qualities of an executive are largely prerequisite to education and not a result of it. The characteristics in an executive which interest us are capable of analysis. I have been asked what qualities I would like in young men. They are very simple: first, a willingness to work; I do not know of any lazy executives, at least they do not remain executives very long; second, intelligence that is adequate to the job; third, a receptive mind. Given these fundamentals, the school and the college can give a man schooling that will help him.

Let me emphasize that whenever a college man is taken into an industry and given any special privileges without regarding the action as an emergency measure and if at the time the men already in the organization are not given an opportunity equal to that of the technical apprentice, the morale of the organization is being broken down. When men are taken into the executive offices from the shop on the same basis as college men are taken from outside and advancements are made at the same rate, the direction in which they can make advancement is as much separated by a bar across which the college man cannot step as some of the lines of ad-

[3] M.S.A.E.—Professor of machine design, Ohio State University, Columbus, Ohio.

[4] White Motor Co., Cleveland.

vancement that are open to college men are separated by a bar across which the men from the shop cannot step. Any system of training future executives that does not recognize the men who are already in the organization is based upon a fallacy.

Few Technically Trained Executives in Industry

Some time ago the National Industrial Conference Board, in cooperation with a committee of the American Society of Mechanical Engineers, collected a mass of information concerning executives in industry, or the number of executive positions. Some of these figures were analyzed and published to show schools how they can cooperate with industry. Nearly 40,000,000 persons in the United States are engaged at present in the mechanical industries. Only 350,000 are college graduates and only 70,000 are from technical schools.

According to the report of the National Industrial Conference Board, approximately 40,000,000 persons are employed in gainful occupations; that is, are earning money for a living. Of this number, including all foremen of whatever kind, about 1,500,000 occupy what might be called administrative, supervisory or technical positions. This is about the ratio of the foreman to the gang, perhaps a little larger, because in the agricultural and household industries people are not working in groups and therefore in industry proper the ratio is less than 1 to 26. Assuming that the men who occupy supervisory or technical positions include the technical experts, as well as major officials, managers, superintendents, technical engineers, designers, draftsmen, inventors, architects, chemists, assayers, metallurgists, auditors, and one-fourth of the foremen, overseers and inspectors, it is found that in 1920 the A class, embracing the chief executives in large establishments, numbered 4000; the B class, embracing chief executives in medium-size establishments, managers in large establishments and eminent scientists, numbered 50,000; the C class, embracing managers in medium-size establishments, superintendents in large establishments, chief engineers and sales managers, numbered 115,000, and the D class, including owners of small establishments, superintendents of medium-size establishments, engineers, salesmen, and one-fourth only of the foremen, numbered 581,000.

This makes a total of 750,000 men in supervisory and technical positions in the mechanical industries. If we add the E class, which includes major and minor executives in all other groups that are gainfully occupied, the grand total is only 760,000. Thus, not more than one-half of the persons holding administrative positions can have had a college or technical education or training. The rest of the 40,000,000 workers comprise class F, which embraces workers, clerks, working foremen, and the like, who are not in supervisory positions. At least half of the future executives will come, as in the past, out of this class, and it is merely a question of how they are to be selected. Some will find their way to opportunity through the evening school, some through the day school, some through the college, some through the correspondence school, and some by virtue of their own ability to absorb knowledge through their work.

Our opportunity and function is to give the man who has the natural ability to handle men and who has intelligence and a receptive mind the information and training from which he may have been debarred through early necessity that sent him to work in the shop at the age of 14 or 16. These are the young men in whom I am deeply interested and in whom industry is most interested. They are the ones, in my opinion, who in the future, as in the past, will have a large share of the administrative and supervisory positions. The number of college men who have the qualities that should be developed in industry is smaller than the number that come up by way of industry. The ratio has been approximately 1 to 10 in the past; not more than one out of 10 executives has been a college man. We must develop the others from the ranks in our shops. We shall also select college men and give them special opportunities when they deserve such treatment, as they will if they have the ability to handle men and enlist cooperation, which, with college training, will enable them to accomplish results.

Training System in the Steel Industry

E. W. Kempton[5]:—In the steel industry we hear frequently statements such as those made at this meeting pertaining to the relative value of the college man and the man who comes up from the mill. I suppose that if a canvass were made of the steel mills of the Country, an extremely small percentage of executives would be found to have completed a college course or even to have started such a course. I frequently find myself doing as others do; that is, pointing with pride to the fact that many of our executives started away down the line. In talking to young men, I tell them that every man in our company who holds a position of manager, came up from the mill, starting as a wire-drawer, spring-machine operator, mechanic, and the like. As Mr. Jones has made plain, the manager is an executive because he "puts things across." These men progressed because they "put things across" even in minor positions.

I believe, from a statement Mr. Younger made, that 80 per cent of the students at Ohio State University are contributing something toward their college expenses and that 25 per cent are paying all of their expenses. We will find that same condition in many other colleges today. These young men will be able to get results because, if a young man can put in the time and mental work necessary to master an engineering course and at the same time do productive work outside of the college, he is already "putting something across."

That is my argument to my company when I say,

> Yes, it is true that the large majority of the older executives came up from the mill, but boys such as you were are going to college today.

I believe that this largely is true; not in its entirety, because extraordinary conditions often enter, but the average young man who has the ability to get things done and in addition possesses the other qualifications to make an executive, can in some way, such as working his way through a regular college, attending a cooperative college or by taking a correspondence-school course, secure an engineering training. However, we in the American Steel & Wire Co. also realize that some men in the mill will make just as good executives in control of a department as will a college man.

Had I heard Mr. Younger's paper a month ago, I should simply have told what my company is trying to do to rescue some of the young college men from the electrical companies, but during the last 2 weeks I have visited a number of colleges and have had an interesting experience. I found that the young men are not fearing the step from school into industry; in fact, they made me rather reluctant about presenting my proposal to them because, at Ohio State University, I was preceded

[5] Educational director, American Steel & Wire Co., Cleveland.

by the representatives of more than 35 companies who had come picturing in glowing terms the opportunities offered by their industries. At the Carnegie School of Technology, the University of Pittsburgh and Lafayette and Lehigh Universities, I was preceded by many and was told by the professors in a rather consoling way, "You are rather late, the cream of the class has been selected, but you may talk to a few who are left."

We are not taking young college men, as many companies are doing, and placing them in a plant and saying,

> We will put you through a course of study during which we will pay you $125 per month and give you 1 year's training, after which we will give you a good job.

What chance did I have when I told them,

> I will give you a job at 50 cents per hr. and at the end of 1 year, if you show that you are above the average in the possession of backbone and ability, we will put you in a training class and that training will be for 2 years and will be hard work. It will include work at the blast furnace, the open-hearth furnace, the bessemer department, and the rolling-mills. You will be expected to go into the wire mills and draw wire, and to do similar work in each department. At the end of this 2-years' course you will have some knowledge and experience that will be of value to you.

We are proud of our proposition. I believe we are on the right track. I think that the year of probationary employment during which time we put these young men in the mill with other workmen is necessary. It gives them an opportunity to show of what stuff they are made and to make an impression on our executives. They are selected on the basis of that impression and that is right. We have lost only one graduate of this course, and he decided that the steel industry was not the place for him. I believe our results have justified the method. Great care should be taken in the selection of these men, otherwise men of much ability in the mill will be justified in saying to or of the company, "What kind of a chance have we?"

We do not restrict this course entirely to the technical graduate; any young man of conspicuous ability may be selected. We do, however, require that at least three-fourths of the appointments made shall be among those who have had a technical training. Other courses of training are always open to every man of ability.

I believe that industry at large, in training men as future executives, will tend to adopt a period of probationary employment during which time the characteristics of the young men can be ascertained and to make sure that worthy young men already in the organization will not be neglected to favor college men who may not be so worthy.

College Men Better Fitted for Selling

B. H. Blair[6]:—We do not have many technical men in our company but we have a number of young men who graduated from the Case School of Applied Science and started at the bottom. We put them on the testing-machine, lifting springs to the machine, putting the load on it, and checking the spring defects. They soon learn from observation what a spring should be. They will not be satisfied to do that work very long; 3 or 4 months is enough to give them plenty of experience. Then they have gone into the engineering department and made designs and checked them. After a certain time they have the opportunity to go out on the road to sell. The man who has the ability to talk to people has the first chance. It is rather unusual that the technical man has the ability to stand up and talk to others. When I was in the Case School the English course was the most disliked and most avoided of any. I think instruction in English is one thing that should be emphasized more in a technical school. Some men in schools like Western Reserve are able to out-talk the head of the company. In selling positions the technical man should be able to make a better selling talk than the non-technical man.

In this way we have been able to get at least five or six men who have taken sales positions or have gone out to the service stations and the results have been good. The men who show stamina enough to stick through the hard preliminary course are the ones who will do well when they go out either as sales representatives or in positions in which they must depend upon themselves.

Course in Steel Mill Demands Intelligence

Mr. Kempton:—We place a man or boy for 1 year on a real producing-job where he can learn something. He may serve on a dozen different jobs but he may remain on one job because he does not develop the required initiative and ability. When I stated that we start the apprentice at the blast furnace, I did not go into details, but I did not mean to imply that he was given only manual labor. He is given a variety of work that, although it begins with labor, progresses so that at the end of 3 months at the furnace he also has had experience as a blower. At the open-hearth he remains on a job in the pit only a few days but he is at the open-hearth for 3 months. At the end of this period he can make a heat of steel, which may contain 60 to 70 tons of metal, and that is worth something. He has to order the material for charging the furnace, work the heat and order his additions for the ladle; he must judge the temperature and tapping time and oversee the opening of the tapping hole. He must give orders for the making of that heat of steel from beginning to end. It is not a plodder's job; the man, to do that, must have intelligence and ability.

Mr. Jones:—If one wants to secure young men who have perseverance he should not paint a rosy picture; otherwise he will get the weak-spirited boys who are looking for an easy job. The proposal should be put to the graduates in its rough aspects. If that does not appeal to some, keep on until it does appeal to others. Mr. Kempton, did you have any trouble in securing men after telling them about the procedure in your company?

Mr. Kempton:—Although I was late in going after them, I have about 50 applicants. Not all of these are in earnest, perhaps, but I do not anticipate any great difficulty in securing the 15 that we shall employ.

College and Shop Training Both Needed

A Member:—My thought before I went to college, and it is the same since I came out about 8 years ago, is that the man who has ambition in the mill or down near the bottom in an organization has a chance to get along better than the college man, because he is getting practical experience. The college man must secure that after leaving college. It seems to me that some way should be found in which industry can cooperate with the colleges whereby the student, during his course of theoretical training, can also obtain the practical training so that at the end of the 4 years he will have the same experience as the man in the mill plus the theory and technical knowledge.

A Member:—Four dominating factors combine to make an executive. One is knowledge; another is judg-

[6] M.S.A.E.—Chief engineer, spring and bumper division, Perfection Spring division, Eaton Axle & Spring Co., Cleveland.

ment; the third is grit; and the fourth is so-called common-sense, which is acquired more rapidly in the school of hard knocks than in college. After the War our company decided that it should bring into the organization a few educated men and it employed three college graduates and gave them executive positions. Later the president employed another and then another and put them in executive positions, but at the end of the year we learned that we had made a great mistake and had failed to recognize the lads who had been brought up through the ranks.

J. W. SAFFOLD[†]:—I have great respect for the men who come up through the hard dirty work in the shop, but the ability to think in an orderly way is invaluable and that is gained through training, which is what education is for. Both education and experience are needed. One without the other will not do.

AUTOMOTIVE INDUSTRY NEEDS BETTER-TRAINED MEN

JOHN YOUNGER:—Formerly the young men who went to college came from wealthy or well-to-do families but today the man with little money can go. At Ohio State University we have one student who fires an engine on the Big Four Railroad three nights a week on an 8-hr. shift and he is a first-class student. Other students are doing all sorts of work. They are not the sons of wealthy men but in some cases are the sons of men in the shops who have realized their own deficiencies and are encouraging their boys to acquire an education. These boys are from the rank and file but they have ambition and want to improve themselves.

The company referred to by a previous speaker made the great mistake of putting college graduates in executive positions. It used to be thought that a college man should go into an executive position at once. We are doing our best to change that idea and are trying to point out that college training merely provides the foundation and not even the base. The graduates must have the after-training to develop them.

Men are divided into two classes: workers on one side and thinkers and planners on the other. Workers can be trained in the shops in 6 hr. A man can be trained in 3 or 4 hr. at the Ford plant and so long as the Ford Company exists he can continue to draw his $7 or so per day. We men in this Society do not want to be in that class; we want to direct others and must have the technical background to do it. The college provides that background, but it is incumbent on the student to paint the picture on it and he can do that only with the knowledge acquired in his later experience.

I am thinking of tomorrow's men. The automotive industry, as a whole, is not training its executives other than as I have said. It has not seemed to be interested, but the fact that only a small percentage of the men in the industry are college graduates does not prove that this will be the fact always. The days of hit-or-miss methods in the industry are past. We must reply upon physics and chemistry and all the other sciences today to excel.

I do not think the morale of a shop will suffer if college men are employed on an intelligent plan. They certainly should not be set on a pinnacle. The men in the shops will send their sons to college and these sons are the men that should be taken into the industry. They will get the technical background and become the executives of tomorrow. The men of tomorrow will be better trained than are the men of today.

[†] A.S.A.E.—President and sales manager, Devices Development Co., Cleveland.

HIGHWAY SAFETY

TO emphasize the importance of the problem of highway safety is not necessary. The probable loss of some 25,000 lives annually, not to mention several times that number of injuries, cannot be taken lightly. On the other hand, to look too much on the dark side of this picture may not be well. The loss of life represents about 1 fatality per 1000 years of automobile operation, or perhaps one per 15,000,000 or 20,000,000 passenger-miles traveled. These figures include not only the occupants of vehicles but also all other users of the road; as a matter of fact, accident records show that the latter represent roughly 65 per cent of the total number of fatalities.

Comparing this with the records for the railways of the Country, the figures are 18,000,000 passenger-miles per fatality. It may be said by way of encouragement that the figure of 1 fatality per 1000 years of driving represents an improvement of nearly 50 per cent within the last 10 years on the ratio of accidents to vehicles, notwithstanding the fact that the total number of fatalities has increased enormously. This improvement is due to various causes, notably the Nation-wide attention that has been focussed on what we may term the abstract idea of safety. The minds of drivers and the general public have been insistently assailed by the safety idea, often with much emphasis on the more spectacular sources of danger in contrast to the commoner and more important ones.

We can safely say that the average citizen who is not familiar with the facts would rate fatalities at railroad grade-crossings as one of the most important hazards of the highway. As a matter of fact, however, such accidents represent about 4 per cent of the fatalities and a far smaller percentage of injuries.

Consideration of what has been and is being done in the interest of highway safety suggests that the various causes of accidents have been very well summarized, that much has been done toward the formulation of uniform legislation and that education and propaganda have received considerable attention, but that much less has been done in the way of research into the basic and less obvious causes of accident and into the possibilities of their elimination.

SKIDDING

Wet roads have been found to be usually as safe as dry roads as regards ability to stop, but sporadic cases occur when this is not true; when the holding power of tires is reduced to 1/10 or less of its normal value. These occasional conditions probably account for most wet-road accidents.

The coefficient of sliding friction between tire rubber and clean hard road surfaces, dry or wet, is usually 0.7 or 0.8, but instances are found on apparently clean wet roads where this coefficient is less than 0.1. This statement refers only to cases where no reason for this abnormal value of the coefficient of friction is apparent. Under such conditions even a very moderate application of the brakes might lead to a dangerous skid.

These occasional slippery road conditions seem to present a safety problem that the highway builder alone can solve, and to arrive at a solution he will need accurate data on the causes that produce these conditions.—From an address by Dr. H. C. Dickinson before the Highway Research Board.

Ultraviolet Spectroscopy of Engine-Fuel Flames

By G. L. Clark[1] and A. L. Henne[2]

Annual Meeting Paper *Illustrated with* Photographs

ABSTRACT

DETAILS are given of the method of control of the engine so that quantitative and reproducible measurements of detonation and comparisons with spectra can be made. Typical data are tabulated and photographs are shown of the free-burning flames of hydrogen, carbon monoxide, methane, gasoline in a blow-torch, and the like. The spectra of explosion and of detonation in the engine confirm earlier conclusions. By means of a synchronous shutter, the spectra of radiation during the four quarters of a stroke are obtained for straight-run gasoline under detonating and non-detonating conditions for the same fuel containing tetraethyl lead, aniline and iodine as knock suppressers and for cracked-gasoline blends. The outstanding result is that, during detonation, the first-quarter spectrum extends far into the ultraviolet, that of the second quarter, a somewhat less distance; the third and fourth quarters are characterized by very little radiation energy. During normal explosion, or when knock suppressers, irrespective of their chemical nature, are used in the engine under detonating conditions, the spectra of all four quarters have the same length and essentially the same intensity. Lead emission-lines from tetraethyl lead appear only in the first quarter. These and other facts are considered in the light of theories of the mechanism of knock suppressers and inducers.

THE ultraviolet spectroscopy of the flames of engine fuels has been recently studied by G. L. Clark and W. C. Thee[3]. Among other conclusions, the fact is pointed out that the spectra of detonation are characterized, under certain conditions, by a strongly banded structure, and that the use of true antiknock material, when added in very small quantities to a fuel, cuts down the part of the spectrum extending into the far ultraviolet.

The purpose of this work is to

(1) Check, under more perfectly controlled experimental conditions, the earlier results
(2) Study the relation between the banded spectra, given by detonation in an internal-combustion engine, and the spectra given by the ordinary flames of various gases burning freely in air
(3) Investigate in greater detail the action of tetraethyl lead on the spectrum of detonation and also that of differently constituted knock-suppressers, such as aniline and iodine, and of non-knocking fuels containing unsaturated products, such as cracked gasoline
(4) Study the reaction of explosion and detonation at various parts of the engine stroke

Spectra of Flames

The ultraviolet spectra of the combustion of various gases have been photographed with the idea of getting a material that could be used as a basis for studying the reactions taking place when a mixture of a hydrocarbon and air explodes in the reaction-chamber of an engine. The principal reactions that one might expect to obtain, excluding intermediate oxidation products, are

(1) Oxidation of the hydrocarbon, with formation of water and carbon dioxide in the case of complete combustion
(2) Formation of some cyanogen, by the combination of the carbon with the nitrogen of the air
(3) Formation of carbon monoxide in an incomplete combustion
(4) Oxidation of carbon monoxide to the dioxide
(5) Oxidation of hydrogen and the formation of water

Since all these reactions take place in air, it seems reasonable to duplicate them by burning these gases in air and thus to photograph the spectra of the ordinary flames of burning hydrocarbons, carbon monoxide and hydrogen. The experiments are not difficult to perform. For a hydrocarbon, one may use illuminating gas, very rich in methane. Carbon monoxide and hydrogen are not difficult to obtain.

The results are given in Fig. 1. All the spectra are referred to a standard spectrum of mercury. A Gaertner quartz-prism spectograph was used in all the work reported in this paper.

Spectrum 2—*Hydrogen.*—A current of pure hydrogen from a storage-tank was burned at the end of a quartz tube to avoid the parasitic lines from a metal or a glass tube. The spectrum extends from about λ3290 to λ2811. One band is very strongly marked; its wave-length is λ3064. W. W. Watson[4] has recently shown that this band has nine satellites. It is generally ascribed to water. Three other bands appear more faintly, the strongest of which, with the head at λ2811, belongs also to water. The two others have wave-lengths of about λ2900 and λ2970 and are undoubtedly parts of the λ2811 band, which extends from λ2811 to λ3057.

Spectra 3 *to* 5—*Moist Carbon Monoxide.*—Carbon monoxide has been obtained from formic acid by dehydration with concentrated sulphuric acid. Washed only in a basic solution, to get rid of both carbon dioxide and formic acid vapors, the gas has been burned at the end of the quartz tube previously used for burning hydrogen. The length of the spectrum extends from about λ5000 to practically λ2200. It is continuous. Only one band is very sharply marked; its measurement gives λ3064, which leads to the conclusion that it must be a "steam" line. This is perfectly admissible, neither the gas nor the air having been dried.

To make this point clear, the run has been duplicated with perfectly dry reagents. The carbon monoxide, made as before, has been collected over water. After a sufficient amount had been obtained, it was bubbled through concentrated sulphuric acid, then conducted through a tube of phosphorous trioxide to the quartz-tube burner. The air from a blast that had been dried by the same

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[2] Fellow of the Chemical Research Board Foundation, Massachusetts Institute of Technology, Cambridge, Mass.
[3] See *Industrial and Engineering Chemistry*, May, 1926, p. 528.
[4] See *Nature*, Jan. 30, 1926, p. 157.

substances was blown through a pipe concentric with the quartz tube, to assure a dry atmosphere.

Spectra 7 *and* 8—*Dry Carbon Monoxide.*—As predicted the λ3064 band disappeared completely, the spectrum remaining unchanged, that is, it remained continuous and had the same length as before the drying. These and other observations confirm the results of F. R. Weston working in Prof. W. A. Bone's laboratory[5] to the effect that, in a flame of pure undried carbon monoxide two sets of independent reactions occur simultaneously: (*a*) direct interaction between the carbon monoxide and the carbon dioxide, exciting radiations that give rise to the continuous and banded parts of the spectrum, to the characteristic blue color of the flame and to the activating of nitrogen; and (*b*) interaction between the carbon monoxide and the water molecules from which originate the steam lines in the spectrum. A mixture of carbon monoxide and hydrogen in equal proportions burns exclusively as the second type of reaction. At high pressures, the first type is favored so that very dry mixtures of carbon monoxide and oxygen or of air, may be ignited by sparks.

Spectra 11 *and* 12—*Illuminating-Gas with Luminous Flame.*—Burned under the same conditions as hydrogen, illuminating-gas gives two different spectra, which correspond to the yellow and to the blue flame. The only band visible on spectra 11 and 12 is λ3064. Beyond this line, it is very faint and noticeable only on the negative plate. It does not extend beyond λ2975.

Spectra 13 *and* 14—*Illuminating-Gas with Blue Flame.*—The steam lines or band-heads, which were previously found in the spectrum of burning hydrogen, are evident. The whole spectrum ranges between λ4430 and λ2810.

Spectra 17 *and* 18—*Illuminating-Gas and Tetraethyl Lead.*—To see whether the presence of an antiknock compound would modify the structure of the spectrum, illuminating-gas was bubbled through liquid tetraethyl lead. The spectrum obtained by this method shows several emission-lines but they all, in addition to λ3064, the steam line, the intensity of which appears to be considerably decreased, are to be attributed to the lead; λ4058, λ3683 and λ3639 are by far the most predominant. It may be noticed, in addition, that the banded structure is accentuated at the expense of the continuous.

Spectra 21 *to* 23—*Gasoline in a Blow-Torch.*—The spectrum of the blue flame taken for various brands of gasoline was substantially the same as that of illuminating-gas when burning with a blue flame, namely, only one strong line, λ3064. Three weak ones could be detected and were attributed to water. It is noteworthy that the strong hydrocarbon band at λ4314, usually observed in liquid-hydrocarbon combustion, is apparently not present.

Summary

Although these experiments do not greatly assist in the interpretation of the explosive reactions in an internal-combustion engine, they are interesting in showing the value of the spectroscopic method. Alternative oxidation mechanisms are clearly shown in the case of carbon monoxide, depending upon the moisture and the pressure. Different reaction-routes are more difficult to prove in the case of hydrocarbons such as methane and the liquid fuels, since the spectra invariably show the λ3064 steam line. The reactions in a blow-torch and in an engine under compression would be expected to be essentially the same from the standpoint of spectra that are integrating and probably cannot be differentiated from alternative oxidation routes to the same end. The absence of the λ4314 band in the free flame, however, is significant from the energy point of view. Again, because the spectra are integrating, tetraethyl lead apparently has little effect upon the spectra of the free flames. Its effect, evidently, is marked only under conditions of detonation.

Spectra of Explosions in an Engine

The engine used for these experiments is the Delco single-cylinder engine provided with the quartz window described by Clark and Thee. The crankshaft of the explosion engine is directly mounted on the shaft of a dynamo, the connections of which are designed in such a way that it can be used as a starting-motor to revolve the crankshaft and later as a generator. The simple operation of the three-way switch from the upper to the

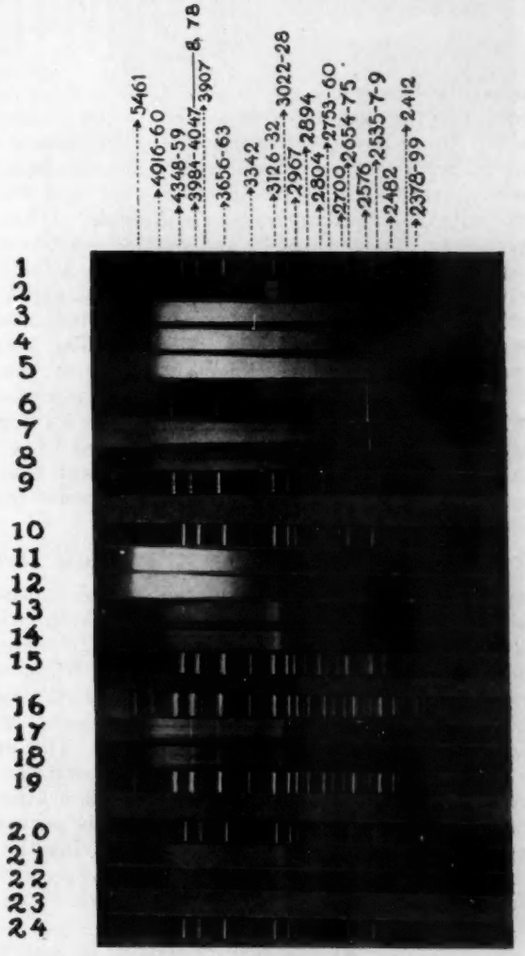


Fig. 1—Ultraviolet Spectra of Gases
These Spectra Were Obtained by Photographing the Combustion of the Various Gases in Air. This Was Done To Secure a Basis for Studying the Reactions Taking Place When a Hydrocarbon-Air Mixture Explodes in the Combustion-Chamber of an Engine.

The Various Gases Are Listed Below

No.	Gas
1	Mercury Arc
2	Hydrogen
3–5	Wet Carbon Monoxide
6	Mercury Arc
7 and 8	Dry Carbon Monoxide
9 and 10	Mercury Arc
11 and 12	Illuminating Gas, Yellow Flame
13 and 14	Illuminating Gas, Blue Flame
15 and 16	Mercury Arc
17 and 18	Illuminating Gas That Was Bubbled through Liquid Tetraethyl Lead
19 and 20	Mercury Arc
21 and 22	Gasoline A in Blow-Torch
23	Gasoline B in Blow-Torch
24	Mercury Arc

[5] See *Proceedings of the Royal Society of London*, vol. 109 A, pp. 176 and 523; also vol. 110 A, pp. 615 and 634.

TABLE 1—RESULTS OF THE KNOCKING OBTAINED IN COMPARATIVE TESTS OF SAMPLES OF FUEL

Kind of Fuel	Temperature, Millivolts	Speed, R.P.M.	Load, Volts	Load, Amp.	Knock, Cc. per Min.
Commercial Straight-Run Gasoline	8.9	1,240	99	10.5	3.40
	8.9	1,240	100	11.0	3.40
	8.9	1,240	100	11.0	3.35
	8.9	1,240	100	11.0	3.35
Commercial Ethyl Gasoline	8.9	1,260	107	12.0	2.18
	8.9	1,260	107	12.0	2.20
	8.9	1,270	107	12.0	2.21
	8.9	1,280	107	12.0	2.21
	8.9	1,280	107	12.0	2.20
Rich Blend of Cracked Gasoline	8.9	1,260	106	12.0	2.20
	8.9	1,280	106	12.0	2.21
	8.9	1,280	106	12.0	2.21
	8.9	1,280	106	12.0	2.20
Commercial Straight-Run Gasoline	8.9	1,280	104	11.5	3.40
	8.9	1,250	100	11.0	3.35
	8.9	1,250	100	11.0	3.35
	8.9	1,260	100	11.5	3.35
	8.9	1,260	101	11.5	3.40
	8.9	1,260	101	11.5	3.42
	8.9	1,260	101	11.5	3.38
	8.9	1,260	102	11.5	3.35

lower positions ensures the change from starter to generator. Cooling has been produced by two adjustable fans, but these have been replaced by a blower directly connected with an outer metal shield for the motor. A rheostat governs the speed of the blower and very accurate control of the temperature is possible. Dials allow the positions of the throttle and of the needle-valve of the carbureter to be accurately controlled. A calibrated speedometer gives the revolutions per minute, and a milliammeter connected with a thermocouple indicates the temperature of the wall of the cylinder. The knocking was recorded by a Midgley knock-indicator or bouncing pin. The compression of the engine was maintained at 4.7, when spectra were to be taken. It was 5.1 for only a few tests. The engine load was controlled by a panel of electric-light bulbs for coarse adjustment that was connected in series with a variable resistance for fine adjustment.

Engine Control and Typical Numerical Data

The most important point to be observed in spectroscopic study is to maintain regular knocking without changing the adjustments of the engine. To make this feasible, the engine was first run without being cooled by the fans with a sufficient load to produce a very audible knocking. The bouncing pin was then adjusted to give a reading of from 1.0 to 1.5 cc. per min. The engine being cold, the run could be started again and the load operated in such a way that the desired knocking was reached in not less than ½ hr. During this period, the cooling was progressively increased by revolving the fans more rapidly. When the desired knocking was thus obtained, it could be made constant by the single resistance. When the equilibrium was reached, very small modifications of the rheostat had a marked effect on the knocking. This method proved to be both sensitive and accurate. Constant knocking was maintained for 1 hr. in the average runs and for 4 hr. in the best runs. As an example of the results obtained from comparative tests of different samples of fuels may be cited the following series in which straight-run gasoline was run first, then the same fuel containing tetraethyl lead, then a cracked-gasoline blend, and last the first straight-run fuel.

Considering the large number of variables that must be controlled, these results are very satisfactory. As further evidence of control, average values of four series of experiments, from which the deviations were no larger than those in Table 1, were chosen at random and are presented in Table 2.

Spectographic Method

Data such as those in Tables 1 and 2, have been obtained during all the runs in which the spectra of the reaction in the engine have been photographed to assure constant conditions and to assist in the interpretation and comparison of the ultraviolet spectra. These were photographed through a quartz window mounted in the side of the cylinder of the engine as previously described.

To photograph a definite part of the stroke, a synchronous shutter was mounted on the shaft of the dynamo. It was actuated by gearing in such a way that one revolution of the shutter corresponded to two revolutions of the shaft, that is, a complete cycle of the engine. The 90-deg. aperture cut in the shutter allowed exposure to one-half or even one-quarter of the stroke but was not sensitive enough to give shorter parts.

The various runs were made under three different conditions:

(1) By suitable adjustments, the engine could be used without any appearance of knocking
(2) By increasing the load and requiring the engine to do more work, the constant knocking effect took place
(3) By using all the adjustments of the type-(2) runs, but with the addition of knock suppressers, the engine was operated without knocking and the output of power remained unchanged

The average conditions for all the runs were: speed, 1080 r.p.m.; load, 90 volts and 6.5 amp.; knocking, 1.5 cc. per min. during detonation, or less than 0.2 cc. in explosions.

Discussion of Spectra

A series of typical spectra is reproduced in Fig. 2, several mercury-arc line spectra being included for reference.

Spectra 2 and 3.—These runs correspond to the whole

TABLE 2—AVERAGE VALUES OF KNOCKING OBTAINED FROM FOUR SERIES OF EXPERIMENTS

Fuel	Compression-Ratio	Temperature, Millivolts	Speed, R.P.M.	Load, Volts	Load, Amp.	Knocking, Cc. Per Min.
Straight-Run Gasoline	4.7	10.8	1,080	91	8.2	2.00
Ethyl Gasoline	4.7	10.8	1,080	90	7.8	1.45
Cracked Gasoline, 50-Per Cent Blend	4.7	10.8	1,080	89	7.9	1.49
Cracked Gasoline, 60-Per Cent Blend	4.7	10.8	1,080	89	7.9	1.43
Straight-Run Gasoline	4.7	9.1	1,080	79	12.0	2.25
Ethyl Gasoline	4.7	9.1	1,080	80	12.0	1.70
Cracked Gasoline, 60-Per Cent Blend	4.7	9.1	1,080	80	12.0	1.73
Straight-Run Gasoline	5.1	8.9	1,180	108	10.5	3.29
Ethyl Gasoline	5.1	8.9	1,180	108	10.5	1.75
Cracked Gasoline, 50-Per Cent Blend	5.1	8.9	1,180	108	10.5	2.10
Cracked Gasoline, 60-Per Cent Blend	5.1	8.9	1,180	108	10.5	1.76
Straight-Run Gasoline	5.1	8.9	1,240	100	11.0	3.37
Ethyl Gasoline	5.1	8.9	1,260	107	12.0	2.20
Cracked Gasoline, 60-Per Cent Blend	5.1	8.9	1,260	106	12.0	2.20

stroke of a knocking engine. The most surprising result is the length of the spectrum. Clark and Thee have already pointed out that the extension into the far ultraviolet is observed when a strong knocking occurs; but the limit of their spectra was λ2811, and the range between λ3064 and λ2811 was very faintly visible. On the other hand, they found that these spectra show bands. In the case of run No. 2, the spectrum extends from the visible to λ2360. Two steam lines λ3064 and λ2811 are well marked. No others could be detected.

Spectra 6 *and* 7.—These correspond to the first half of the stroke with the engine knocking sharply. Both had the same time of exposure, that is, 2 hr. The spectrum of the first half was substantially the same as that obtained under the same conditions for the whole stroke, that is, the length and the recorded lines were the same. The intensity of the plate was lower, but no conclusions could be drawn from this fact, because the adjustment of the slit of the spectroscope was different in both cases.

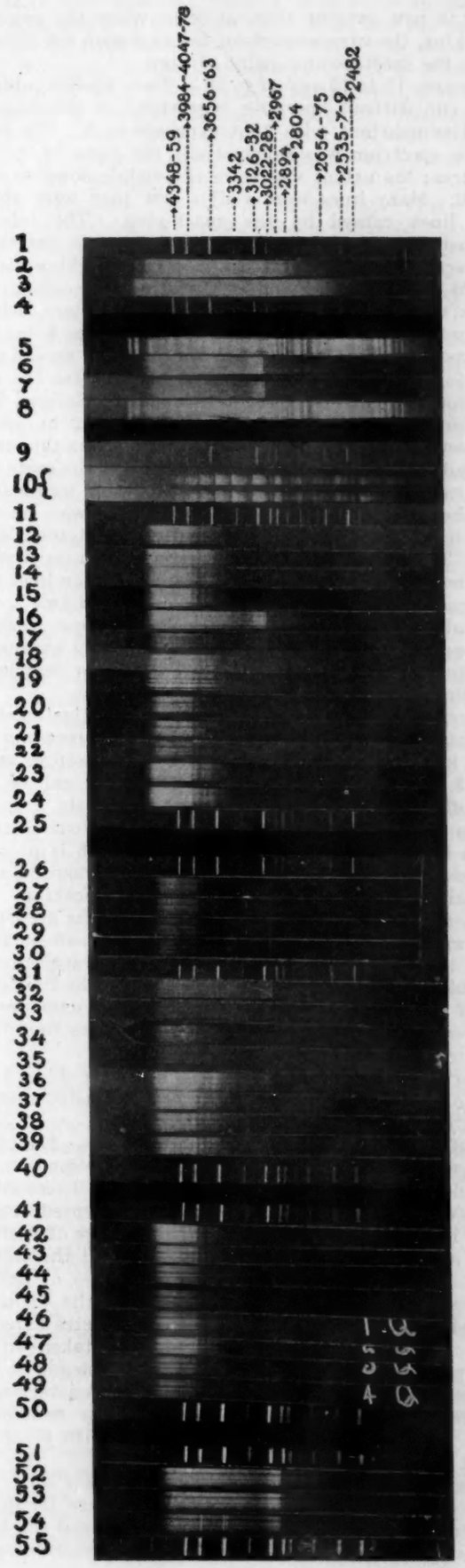
For the second half, all the conditions were the same as for the first, including the setting of the spectroscope. In spite of these facts, the intensity was so faint that the spectrum was visible only on the negative plate. Its limit toward the short wave-lengths was at about λ3650; on the other side, it reached the visible. No lines could be detected.

FIG. 2—ULTRAVIOLET SPECTRA OF FUELS TESTED

These Spectra Were Photographed through a Quartz Window in the Side of the Engine Cylinder. Special Arrangements Were Made To Enable the Desired Part of the Explosion To Be Photographed. Data on the Different Spectra Are Presented Below

No.	Fuel	Detonation or Explosion	Part of Stroke	Length of Run, Hr.
1	Mercury Arc	.....	.....	..
2 and 3	Reference Gasoline	Detonation	Full Stroke	2
4 and 5	Mercury Arc	.....	.....	..
6 and 7	Reference Gasoline	Detonation	First Half	2
8 and 9	Mercury Arc	.....	.....	..
10	Spark-Plug	.....	.....	2
11	Mercury Arc	.....	.....	..
12	Reference Gasoline	Explosion	First Quarter	2
13	Reference Gasoline	Explosion	Second Quarter	2
14	Reference Gasoline	Explosion	Third Quarter	2
15	Reference Gasoline	Explosion	Fourth Quarter	2
16	Reference Gasoline	Detonation	First Quarter	1
17	Reference Gasoline	Detonation	Second Quarter	1
18	Reference Gasoline	Detonation	Third Quarter	4
19	Reference Gasoline	Detonation	Fourth Quarter	4
20	Reference Gasoline Plus 3 Cc. of Tetraethyl Lead per Gallon	Explosion	Full Stroke	1
21		Explosion	First Quarter	1
22		Explosion	Second Quarter	1
23		Explosion	Third Quarter	4
24		Explosion	Fourth Quarter	4
25 and 26	Mercury Arc	.....	.....	..
27	Reference Gasoline	Explosion	First Quarter	2
28[a]	Reference Gasoline	Explosion	Second Quarter	2
29[a]	Reference Gasoline	Explosion	Third Quarter	2
30[a]	Reference Gasoline	Explosion	Fourth Quarter	2
31	Mercury Arc	.....	.....	..
32[b]	Reference Gasoline	Detonation	First Quarter	2
33[b]	Reference Gasoline	Detonation	Second Quarter	2
34[b]	Reference Gasoline	Detonation	Third Quarter	2
35[b]	Reference Gasoline	Detonation	Fourth Quarter	2
36[c]	Reference Gasoline Plus 3 Cc. of Tetraethyl Lead per Gallon	Explosion	First Quarter	2
37[c]		Explosion	Second Quarter	2
38[c]		Explosion	Third Quarter	2
39[c]		Explosion	Fourth Quarter	2
40 and 41	Mercury Arc	.....	.....	..
42	Reference Gasoline Plus 3 Per Cent of Aniline	Explosion	First Quarter	1½
43		Explosion	Second Quarter	1½
44		Explosion	Third Quarter	1½
45		Explosion	Fourth Quarter	1½
46	Reference Gasoline Plus 3 Per Cent of Iodine	Explosion	First Quarter	1½
47		Explosion	Second Quarter	1½
48		Explosion	Third Quarter	1½
49		Explosion	Fourth Quarter	¾
50 and 51	Mercury Arc	.....	.....	..
52	Reference Gasoline	Detonation	Full Stroke	⅛
53	40 Per Cent of Reference Gasoline and 60 Per Cent of Cracked Smackover Gasoline	Detonation	Full Stroke	⅛
54	Reference Gasoline Plus 3 Cc. of Tetraethyl Lead per Gallon	Detonation	Full Stroke	⅛
55	Mercury Arc	.....	.....	..

[a] Spectra 28, 29 and 30 were photographed on the same plate.
[b] Spectra 32, 33, 34, and 35 were photographed on the same plate.
[c] Spectra 36, 37, 38, and 39 were photographed on the same plate.



It is now evident that, at least when the engine is knocking, the various parts of the explosion are different, from the spectroscopic point of view.

Spectra 12 *to* 15 *and* 27 *to* 30.—These spectra, obtained in a run without knocking, correspond to the four consecutive quarters, with 2-hr. exposure each. The length of the spectrum was substantially the same in the four pictures; the extent was from the visible down to about λ3500. Many lines were visible, but they were absorption lines caused by the spark-plug. The intensity seemed to reach the maximum in the second quarter.

Spectra 16 *to* 19 *and* 32 *to* 35.—The knocking was obtained by overloading and by adjusting the cooling. Pictures were taken of the consecutive quarters, but, on account of the results obtained with spectrum 6, the time of exposure was 1 hr. each for the first and second quarters for spectra 16 and 17, and 4 hr. each for the third and fourth quarters, spectra 18 and 19. Spectra 32 to 35 were all obtained with an exposure of 2 hr. and on the same plate. The first quarter was by far the strongest and the most extended; the length was the same as in spectra 2, 3, 6, and 7; λ3064 and λ2811 were well marked, but the absorption lines of the spark-plug were so weak that it was impossible to be positive about their detection. The second quarter was narrower than the first and does not extend beyond λ3064. The absorption lines from the spark-plug are plainly visible. The last two spectra are substantially the same and look like the corresponding spectra, 14 and 15, for the non-knocking engine, except for the fact that they require a 100-per cent longer exposure.

Spectra 20 *to* 24 *and* 36 *to* 39.—The adjustments of this run are the same as those of the preceding run with knocking, including the time of exposure, except that 3 cc. of tetraethyl lead was added per gal. of fuel. The effect was to reduce the knocking greatly.

The most important result is that the four quarters again have the same length, and this length is precisely the one observed in spectra 27 to 30, corresponding to normal conditions of an engine without knocking. The range is from the visible to about λ3500. The absorption lines are well marked in each picture. The lead emission-lines, which are particularly well shown in spectrum 36, at λ4058, λ3683 and λ3639, appear only in the first quarter of the stroke. The third and fourth quarters are the most intense but correspond to exposures four times as long as those of the first half.

Spectra 42 *to* 45—*Straight-Run Gasoline Plus* 3 *Per Cent of Aniline.*—The machine was so adjusted that the knocking was completely eliminated by the use of 3 per cent of aniline by weight. At the same time, the conditions were such that the use of plain gasoline was impossible without a very audible knocking. These conditions were: temperature, 6.5 millivolts; speed, r.p.m., 1140; load, 96 volts and 8.0 amp. This change of fuel was made several times to be perfectly sure that the absence of detonation was positively due to the use of aniline. As was expected, the four quarters of the explosion seemed to be practically the same. The spectra extended from the visible to about λ3500. Being taken on the same plate, the four quarters are comparable. The first two quarters are slightly more intense, with a very weak maximum in the second one. In short, the results obtained by the use of aniline were similar to those obtained by the use of tetraethyl lead.

Spectra 46 *to* 49—*Straight-Run Gasoline Plus* 3 *Per Cent of Iodine.*—The same precautions were taken for this run as for that immediately preceding and the same results were obtained. Consequently, the shortening of the spectrum can be attributed to the use of iodine. The fourth quarter could not be completed on account of injury to the carbureter by the chemical action of iodine.

Spectra 52 *to* 54.—These spectra correspond to the extreme knocking conditions that are tabulated in Tables 1 and 2. The runs were of 10 min. each, the shutter being removed. As the knocking was very bad, the pictures were taken only during the short time, from 2 to 3 min., during which the conditions were constant. Then the engine was allowed to cool down.

Straight-run gasoline gave the most extended spectrum, about λ2600, corresponding to the worst knocking, 2.20. The cracked-gasoline blend showed nearly the same extent. On the negative, one could notice that the spectrum was slightly shorter, the knocking being equal to 1.75. The spectrum corresponding to the use of tetraethyl lead, for which the knocking was equal to 1.70, was decidedly shorter.

It is interesting to point out that, from the bouncing-pin readings, the second spectrum was expected to be more nearly analogous to the third than to the first, yet the contrary happened. This is to be compared with the fact that, when tetraethyl lead was used, the 10-min. run could be easily performed at one time, whereas the two other fuels required three or four exposures of about 3 min. each to obtain the same result. This is evidence that the mechanism of the antiknock action of tetraethyl lead is distinctly different from the reaction of the cracked or non-knocking fuel whose actual knock-reading on the indicator was of the order of magnitude of ethyl gasoline. It is believed that the ultraviolet spectra involve another important property besides that of indicating knocking. They have convincingly proved that a true antiknock material shortens the ultraviolet spectrum and causes a uniform movement and reaction during the whole stroke, instead of a violent reaction during the first and, to a lesser extent, the second quarter.

Conclusions

When the engine does not knock with ordinary straight-run gasoline, the various quarters of the explosion have substantially the same length, the limit toward the ultraviolet being λ3500. The only visible lines are absorption lines from the spark-plug.

When the engine is knocking, the four quarters are entirely different. The extent of the first reaches λ2360; that of the second, only λ3064; and that of the last two, about λ3500. The observed bands are λ4314, λ3064 and λ2811 in the first; λ3064 alone in the second; and none in the other two. The absorption lines are nearly invisible in the first, noticeable in the second and clearly evident in the third and fourth.

The addition of an antiknock material, such as tetraethyl lead, aniline, iodine, and the like, equalizes the length of the four spectra. They are the same as those obtained when the engine does not knock with straight-run gasoline, although the adjustments of the engine are such that knocking must otherwise occur.

The intensity of distribution seems to give promising results. A comparison of the various prints indicates that the liberation of energy is of the same order of magnitude in the four parts of the explosion when the engine is running normally. A small maximum was found in the second quarter. When the engine knocks, the distribution of the energy must be entirely different, the greater part of the liberation occurring during the first half of the stroke. The second half of the stroke corresponds to only a very low percentage of the liberated energy. When tetraethyl lead, aniline or iodine is added

to the fuel, the immediate effect is a better distribution of the energy among the four quarters of the explosion; this corresponds to a diminution of the ultraviolet emission during the first half, with a corresponding augmentation of the intensity during the second half.

Lead lines in the spectra of fuels containing tetraethyl lead appear only in those taken during the first quarter of the engine stroke, or that portion of the explosive reaction immediately following spark-ignition of the gaseous mixture. This would seem to indicate that the action as an antiknock material occurs throughout the mixture rapidly, probably by thermal decomposition ahead of the explosion wave. If pyrophoric colloidal lead particles are formed which, by their incandescence, act as miniature multiple spark-plugs, their period of emission of characteristic lead-lines during oxidation is limited to the first quarter at least. Precisely the same phenomenon is true when colloidal lead is present initially in the fuel. The recent experiments of Sims and Mardles[6] prove that the colloidal lead initially present has the same antiknock properties as the tetraethyl lead present in equivalent amounts with respect to lead. The same is true for colloidal iron or nickel as compared with their carbonyls. Olin, Read and Goos[7], however, obtained absolutely negative results with colloidal metals. This miniature spark-plug theory is far from being sufficiently comprehensive to explain knock suppression. It does not account for knock induction, nor for the suppressing action of iodine and aniline. Furthermore, colloidal carbon, silver, gold, and the like, and various unstable compounds of aluminum, cobalt, mercury, copper, cerium, chromium, uranium, tungsten, and even of lead and iron, which readily yield colloidal metal, namely, the naphthyls, xylyls, phenyls, and the like, have no effect. The ultraviolet spectra, however, show that all substances which act as knock suppressers have precisely the same effect, in that in their presence there is no emission in the far ultraviolet, such as occurs in detonation, and the energy liberated is distributed throughout the whole stroke instead of largely in the first quarter. This is a further argument in favor of the radiation theory; for certain compounds in their decomposition, possibly momentarily, into free radicals, even C_2H_5 in lead, C_2H_5 and C_6H_5 in aniline, or atoms, I_2 to $2I$, may absorb radiations that activate the gas molecules of the beginning wave and lead to detonation velocities and knocking. This is one way of expressing a gaseous-phase negative catalysis, knock inducers being, very likely, positive catalysts to the oxidation of the hydrocarbon fuel molecules. The pyrophoric colloidal particles may be a secondary phenomenon that has an influence in addition to the principal mechanism and may thus account for the somewhat greater efficiency of such suppressers as tetraethyl lead. Another promising possibility is the Callendar theory that suppressers may prevent the nuclear condensation of highly concentrated, low-igniting droplets of the heavier hydrocarbon fractions, in either of two ways: the suppresser is preferentially adsorbed on finely divided carbon serving as nuclei and thus prevents condensation, in other words, is a poison; or, upon adsorption, it decomposes as a relatively unstable compound and liberates locally heat that redisperses the condensed and easily ignited hydrocarbons.

All these possibilities are amenable to experimental proof, particularly by carefully controlled spectroscopic experiments with a better spectroscope than has been available thus far in this work. Certainly, the mechanism of knock inducers and suppressers is far more complicated than can be adequately accounted for by any of the nine or more theories that have been proposed. David has recently found, for example, that infra-red radiation may be characteristically absorbed by some explosive gases, but not by hydrogen, and the explosion velocity increased but only in the presence of nitrogen, which plays some obscure but important role.

[6] See *Transactions of the Faraday Society*, October, 1926, p. 363.
[7] See *Industrial and Engineering Chemistry*, December, 1926, p. 1316.

TEN PER CENT MORE MOTOR-VEHICLES

ONE of the most significant facts brought out by the annual statistical review of the automotive industry compiled by the B. F. Goodrich Rubber Co. is that more motor-cars and trucks were produced and sold in 1926 than in any year previous. The motor-vehicle registration showed an increase over 1925, which was not, however, as great as the increase in 1925 over 1924. The total number of motor-vehicles registered in the United States in 1926 was 22,273,643, an increase over 1925 of 2,044,618 vehicles or approximately 10 per cent as compared with a 13-per cent increase in 1925 over 1924. If the total registration is divided into the estimated population of the United States, it will be found that the ratio of one motor-vehicle to every five inhabitants again holds goods. Dividing the area of the Country in square miles into the registration figure shows that a trifle over seven motor cars are used per square mile. The estimated total of passenger-cars and motor trucks built during 1926 was 4,497,390, an increase of 297,390 over 1925.

Increases in the number of cars registered last year were reported in every State of the Union except South Dakota and Utah. On the other hand, another new State, Texas, joined the commonwealths having more than 1,000,000 motor-vehicles registered, the number of these now being seven. New York retains its lead with 1,798,091 motor-vehicles, an increase of 9 per cent over 1925. While California's percentage of increase, 11.8, was greater than New York's, it still remains in the second place with a total registration of 1,614,479. Motor-vehicle registration in Ohio gained 16.2 per cent in 1926 and that State now takes third place with 1,510,000 motor-vehicles registered. Pennsylvania now ranks fourth with a registration of 1,482,837 motor-vehicles, its percentage of gain being only 8.5. Illinois ranks fifth with 1,370,351 registrations, an increase of 8.1 per cent over 1925 and Michigan is sixth with a total registration of 1,122,828, an increase of 11.6 per cent.

For the second consecutive year Florida made the greatest percentage gain of any State, the figure for 1926 being 31.5 per cent as compared with 49.1 per cent for the increase in 1925 over 1924. This gives Florida one motor-vehicle for every 2.2 persons, the highest showing made by any State, California which in 1925 led the procession showing the same ratio in 1926, one motor-vehicle for every 2.4 persons. The State making the next largest percentage gained was Maine with 22.3 per cent.

The automotive industry remains first in rank among all business enterprises based on the value of its finished products, the estimated wholesale value of the motor-vehicle and allied industries products approximating $4,500,000,000. Almost 9,000,000,000 gal. of gasoline was consumed in 1926 by motor-cars in the United States. A veritable network of motor-transportation lines over the Country is formed by more than 500,000 miles of hard-surface highway.

What Sells Motor-Cars?

By R. H. GRANT[1]

ANNUAL DINNER ADDRESS

IF I started in to tell you what sells motor-cars, I would not get through this evening. We had a fellow that started out to write a book on how to sell motor-cars, and it took him a couple of years. When he got through the book was so big that it discouraged everybody that ever looked at it, and nobody has ever used it since it was written. So, instead of tackling the subject that way, I will pick out of my experience a few high-spots that I think will be understandable.

The points that I make will have to be of more or less general nature. I think you will get something out of them but, if we should argue them down to their last analysis, it would take too long. So I want you to understand that these are generalities; you probably will need to put limitations upon certain things I say. First, the thing that sells motor-cars in my estimation is best expressed in this phrase: You sell a number of motor-cars or you don't, according to what the public says about your product. That is the final determination as to the number you sell.

A number of important factors determine what the public says about our product, and they are inter-related. A company may be weak in one of the factors, but very strong in another; so that, when you take an average of the five or six, that company might be weak in one particular and might be pretty strong on the average.

Here are the factors as I see them. First, the design of the car; second, the faithfulness with which the production department carries out the specifications of that design; third, the way you advertise the product; fourth, the way you sell the product, which comprehends the servicing of it; and, fifth, the way your management reflects its ideas out to the public. All those five factors determine whether the public talks about you at all, whether it talks unfavorably about you, or whether it talks favorably. The whole art and science of this thing is to set up the largest amount of favorable talk about your product.

Now let's go back and analyze those factors that determine whether or not the public will be articulate or inarticulate as to your product. Let's leave the design end until the last. On the production end, we have reached a point where anybody who tries to shy on the production and knock down the cost by not keeping up their drawings, by not keeping their tools in shape, by not keeping good machine-tools in the plant, by not having proper working-conditions, for every dollar that they save on the expense end from a production viewpoint they will lose many times that in the loss of sales as soon as the public finds them out; and the public will find us out in 1 year's time after we let the quality of our production slip. We can put it down as an axiom that no money can be saved in attempting to shy production or to make the profit sheet look "good." The public will respond to well-built goods when it has an opportunity, as much as to any factor with which we have to contend.

EFFECTIVE ADVERTISING

Now let's look. We will say that we have a well-designed article, that we build it honestly, that we put into it everything that we should; then, let's look at it from the viewpoint of our translation of it to the public. That brings up the subject of advertising. When you consider the advertising of an automobile, you have to put it in a different category from the advertising of some other kinds of goods. Why? Because the automobile is an article in the public eye. In the smoking-car, in the drawing-room and in any place where people gather, they settle among themselves the automobile supremacies of the United States. Automobiles are in a category with National sports, with moving pictures and any important current topics of the day. Consequently, the advertising reaction about them is entirely different than with some prosaic products about which people do not care to spend their time in discussion. That being the case, there is a better opportunity if you know how to do it to catch the public imagination.

In advertising automobiles, if you can't get the people to talk, your advertising is not very effective. If I had an appropriation of $5,000,000, I would expect to spend $2,000,000 of it in advertising a new automobile merely to lay the background, and I would expect no "kick" out of the public, no word-of-mouth advertising, which is what we are after, until I had laid that background. From then on, I would expect to make the public talk. I think there are advertising managers who do not understand today that the purpose of the advertising is not to make pretty copy and is not to make people read what it is for; what it is for is to make them talk in the smoking-cars and in the drawing-rooms and, until that is done, you are not getting your money's worth out of the advertising that you spend your money for.

THE PSYCHOLOGY OF SELLING

Now we come to the selling end of the proposition. Automobiles, generally speaking, are bought and not sold. I have sat in the center of the industry in a pretty well-known office for 3 years and nobody ever yet asked me to buy an automobile, but many insurance men, many bond salesmen, many solicitors of all kinds have tried to sell me their goods. We do not disturb the public in our industry. We let it alone, and we let customers come as a result of any urge that they may get because they have seen the goods, because somebody has told them about the goods or because they can't wait any longer for somebody to come around and see them. We yet have to put into the sale of automobiles a sufficient amount of intensity so that we will disturb some of the dignified gentlemen of this Land who, uptodate, have had plenty of money but no solicitation to buy one of the most important products in the world. We have to intensify the selling end to get the greatest response, and I think we are in process of doing it.

In addition, we have to take the joke out of service, and we have done considerable in that direction in the industry in the past 2 or 3 years. As I go around the Country, I hear fewer wise-cracks about the terrible service on automobiles. I think most companies are improving and getting their dealer shops on a basis where the customer can really get some service. So, if we know how to capture the public imagination with our advertising, if we know how in the proper kind of way to get

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our salesmen into contact with people, if we give the service that we ought to give, we are making people talk favorably instead of unfavorably about our product; and, as a result, we naturally will sell more motor-cars of some brand that is handled in the right kind of a way. That may not extend the market as a whole, but the market will extend of itself as people understand in a better way than they do today what motoring is doing economically.

More Cars per Family

I think that the use of more cars per family is the obvious way in which this industry will expand in the next 2 or 3 years. The telephone and rapid transportation have made the family more active than it used to be. The idea of a man taking the transportation away from his family, just to get to his work and back, is something that will be an old-fashioned idea. The modern family will have to be served with enough transportation so that all members of it can get more out of life of what there is in life, if they have adequate transportation. From that source alone I think you will find that this market will be expanded in the next year or so from 4,000,000 cars at least to 4,500,000 cars, and I think also that there are further possibilities in that direction.

Coordinated Management

We finally have to come to a management that knows how to take this designing, this production, this advertising, and this selling and coordinate it intelligently so that no one good factor is overcome by improper administration of some other of those factors. In addition, that company, by its reputation, by its acts and by its integrity of purpose, must reflect to the public the same intention that any one of its good departments or divisions reflects. If that is not done, the company by its own management can kill the best production department, it can kill the best sales department and it can kill any part of itself, by not being right as to its main and its general management. From the viewpoint of the engineer, that is a double function. The engineer can produce a car that impresses the public by the obvious things about it, by its appearance. A car's appearance is such an obvious thing that an engineer who turns out a car that is cumbersome in design or that lacks in good appearance certainly ought to be ashamed of himself at this stage of the game, because I think it has been demonstrated so many times that we must be modern in appearance, uptodate in looks, and provide a good and proper atmosphere with the car; that to overlook that requirement would be to offend terribly.

The Public's Test of a Car

Another thing, however, that falls upon the engineer to do cannot be judged so quickly. If his detailed design is such that the car, if it is properly built by the production department, will hold up and function, the public will know it at the end of a year, and the greatest asset a sales department can have is a well-designed car that will stand the public test for a year. Not so long ago a car came on the market that was good to look at and somewhat unusual in design. I had heard through the grapevine that they had been very careful in their road tests, and I said to my associates, "If she works right for a year, if she stands the year's test, the sales department has an easy job." That work of testing and that preparation had been sufficiently good so that the car withstood the test and that company has had a walk-away ever since.

So, the engineer, in working out those things that do not come to the surface quickly, can bank upon it that if the inter-relation of parts and the workings of various parts of the car are good only for a short period, if they can't stand the gruelling test of thousands in use for a year's time, he can pretty well put it down that he has been a detrimental influence to his company. Whereas, on the other hand, if he plans and works the car out so that it stands up and does the work, then he has given to his company the very greatest thing that an engineer can give, because beyond appearance, beyond beauty, beyond anything that can be seen on the surface, the ability of a car over a long period to go out and give satisfaction is the thing to which the public always responds.

In the automobile business you can kid the public for a week, you can k'd it for a month, but nobody has ever yet been smart enough to kid it for a year, and I think there never will be anyone smart enough because the public has become too motorwise as a result of 25 years' experience with our particular type of product. I say to the engineer, regarding his part in this picture and his assistance to the sales department, study the obvious, learn how to make cars look well, learn how to make them look better than they are; but, back of that, put dependability, put proper relation of one part to the other. Don't have any weak links in the chain; make cars so that at the end of a year that crop of customers talks favorably about the product. Then if your advertising department has been slick enough to pick out those things that the public probably would say about that car and to put the words into the customers' mouths and egg them on and help them on, don't you see how, through the engineering and the production and the advertising in combination, you are beginning to build up that word-of-mouth advertising that is the essence of what sells motor cars?

Tell the Truth in Advertising

Some men try to get the public to say about their cars what they don't believe themselves. Some people try to say the opposite thing about the car to what they know is in it, so as to kid the public. You can't do it. We have advanced beyond that stage. We can take only the very obvious things. We can judge only the response that we are pretty sure will come. That is the little bit of flame and then, through our advertising, we must fan that flame into something that burns, which is the public "talk" I have mentioned that constitutes the greatest force in selling motor-cars.

So, my size-up of the situation is this: No department can get away with it by itself. No department is any more important than the other. The designer must know his job. He must build the right design so that the cars will work. The production man can't cheat. If he does, he will kill the company. He must put honest work that is up to the specifications into the job.

The advertising man must be the most truthful man in the institution. He can't make black out of white. He has got to know the public mind. He has got to know where he can make a flame and how he can fan it. The sales department must become less worried about disturbing the public. We have got to disturb the public more. We have got to rap on the door and go in whether the public wants us or not, and learn how to make the public like it.

The service department has got to "be there" with the proper parts and the proper mechanics, and it can't be composed of a bunch of highway robbers. Furthermore,

when the mechanics of the service departments claim that they have fixed something, they actually must have fixed it. A man wants his car quickly and he wants it at a reasonable price. But, above everything else, if you tell him it is fixed, he wants to find that it has been fixed. We have not been doing that in the past, and we have got to do it in the future.

Then, finally, the management as a whole by its intentions, by its reflection of those intentions out to the public, must not kill the work that its several good departments have been able to do, and if we attempt through good management to get all of those various factors, then we get the maximum amount of favorable comment about our product, and that is the way to sell and to keep on selling the maximum number of motor-cars to the inhabitants of the whole world.

MOTORCOACH AND RAILROAD

THE growth of motor transportation has been reflected in the passenger traffic of steam railroads. The number of passenger-miles of operation had been gaining steadily up to about 1920, when a high point of 47,000,000,000 was attained. Thereafter it slumped rapidly, in part, no doubt, due to the depression of 1920 and 1921. In 1925 the total was less than 36,000,000,000 passenger-miles, a drop of nearly 25 per cent despite an appreciable increase in population in the 5-year interval. In the case of some roads the decline has amounted to as much as one-third of the former traffic. A continued decline in earnings from day-coach service is due to the increasing competition of private automobiles and the motorcoach.

While it is usually conceded that expansion in the number of private automobiles has been the main reason for decreased railroad passenger-travel throughout the Country, in certain localities a sizable portion of the aggregate loss has been attributed properly to increased facilities for travel by motorcoaches.

One New England road estimated its annual loss in passenger revenues due to motorcoach competition at $3,328,000 and the loss from private automobile competition at $24,561,000, an aggregate reduction attributed to automotive competition of nearly $27,900,000. This loss amounted to approximately 40 per cent of the total passenger revenue which it was estimated the road might normally have expected. Another railroad engaged principally in short-haul passenger traffic attributed to motorcoach competition a reduction of 25 per cent in passenger business on certain lines. In other localities the effect of competition has also been far-reaching.

Nearly 1200 miles of steam railroads in Massachusetts and Rhode Island are paralleled by motorcoach routes. In Connecticut motorcoach routes parallel more than half of the 1000 miles of railroads. Nearly 3000 miles or over 40 per cent of the steam railroad mileage of Indiana is paralleled by motorcoach routes. This brings into competition with motorcoaches nearly every steam railroad in the State. In Iowa 20 per cent and in Michigan over 30 per cent of the total railroad trackage is paralleled by motorcoach routes. In Connecticut, West Virginia, Kentucky, Arizona, Oregon, and Washington from 60 to 90 per cent of the aggregate mileage of motorcoach routes either parallels steam railroads or competes indirectly by connecting the same terminals. Under such conditions a loss of a considerable volume of traffic is inevitable.

Cost of Motorcoach Operation

It has been estimated that city type motorcoaches running as much as 100 miles per day can be operated for about 30 cents per mile. This includes depreciation, maintenance, insurance, and other items. Operating costs tend to decrease as daily mileage increases up to a certain limit. In North Carolina the operating cost of motorcoaches is reported to average about 18 cents per mile and average gross receipts are 24 cents per mile. From the point of view of capital investment, the motorcoach of course has a substantial advantage over its rail competitors, since it has no fixed investment in right-of-way, roadbed and rails. An estimate by one operator showed that a capital investment of $1.25 in motorcoach systems is required to obtain $1.00 of annual gross revenue, while an investment of $4.00 in street railways is necessary to secure the same gross return.

On some lines in Indiana the average charge per passenger-mile is as low as 2 cents while in Connecticut the average is close to 4 cents. Data are now being collected by the Interstate Commerce Commission to determine the status of motor transportation in relation to the whole competitive structure of the transportation systems of this Country.

Some of the more experienced companies have been operating at a profit, while many of those which have entered the field have suffered loss. In 1925 the 326 motorcoach companies in Ohio operating under the jurisdiction of the Ohio Public Utilities Commission carried 36,588,000 passengers. These companies do not include those operating wholly within cities or between contiguous cities and towns. Total revenue of these companies was $8,614,000 and total expenses were $8,142,000. Three-fourths of the companies operated at a profit and one-fourth at a loss.

Regulation by Interstate Commerce Commission

Railroads engaged in interstate traffic have both passenger and freight rates prescribed by the Interstate Commerce Commission. Earnings are restricted by a provision requiring half of all earnings above a fixed rate on the property involved to revert to a revolving fund that has been established to aid weak roads. Rail operators take the stand that rates charged by competing motorcoach lines and routes that are permitted to be operated should be regulated similarly in accordance with the interests of existing rail transportation facilities. Motorcoach operators on the other hand contend that since the public demands the new form of transportation it should be encouraged even if the railroads suffer a measure of reduced passenger-traffic.

That Federal regulation of interstate carriers is both advisable and not far distant seems highly probable. Rail transport agencies favor such regulation to reduce the present often irresponsible cut-throat competition. Established motorcoach companies also favor regulation for much the same reason. However, the division of authority between Federal and State controlling bodies seems likely to be even more fraught with difficulties in the case of motorcoaches than of other types of common carrier, because they are in essence a local or short-distance means of conveyance. The State of New Jersey affords an illustration here; lines that have their terminals in New York City and Philadelphia operate for well-nigh their total mileage on New Jersey highways. Many other perplexing problems remain to be solved.—*Commerce Monthly.*

ACTIVITIES OF THE SECTIONS

(*Concluded from p. 202*)

102 hp. at 2600 r.p.m. It has four-point suspension, with rubber and fabric shackles at the rear end.

The exhaust-manifold is located on the right and all gases pass over the top of the engine, around a hot-spot in the vertical riser of the manifold and pass out near the front of the engine. The hot-spot is insulated from the carbureter and intake to prevent heat conduction. The heated portion of the riser is approximately 6 in. long. A Perfection hot-air heater is installed on the straight section of the exhaust-pipe below the car frame. All gases in the crankcase are drawn through the carbureter into the engine.

The sedan eight-cylinder model weighs only 10 per cent more than the six-cylinder sedan.

The six-cylinder engine now has a seven-bearing larger-diameter crankshaft with 43 per cent more bearing area, longer sleeve-stroke which gives 30 per cent greater port opening, a three-port inlet manifold with each pair of cylinders siamesed, and develops 82 hp. at 2600 r.p.m.

Rear-axle drive is by Timken worm and gear in both the six and eight-cylinder cars, and Bendix brakes are used on both.

Velie Has Added a Small Six

A small six-cylinder car in four-door sedan and two-passenger coupe models has been added to the Velie line. As described by H. C. Snow, chief engineer, it has a 112-in. wheelbase and the sedan weighs aproximately 400 lb. less than the sedan of the larger model. The engine has 196-cu. in. displacement. With the decreased weight, the small six gives practically the same performance as the larger one. The general design of the two is the same.

The piston-ring arrangement differs from conventional practice. The two top-rings are plain and ⅛ in. wide. The third ring is of the oil-control type, with holes drilled in the bottom of the groove. The fourth is placed below the piston-pin and is 3/16 in. wide, and the bottom of the groove is drilled for oil return. This arrangement has been found most satisfactory as regards oil consumption, piston slap and uniform cylinder-wear.

A Lanchester-type vibration damper is mounted on the front end of the crankshaft. Extremely quiet valve-operation is secured by feeding oil under full pressure to all bearings of the rocker-arms through holes drilled in the valve rocker-shaft and feeding a stream of oil upon the ball-and-socket connection at the top, whence it flows along the push-rods to the valve tappet. Another aid to quietness is the contour of the valve-operating cams, which have a lift of 0.001 in. for each 5 deg. of turning angle of the camshaft, so that at an engine-speed of 1000 r.p.m. the velocity of the rocker-arm against the valve-stem and of the valve head against its seat is about ⅝ in. per sec.

Hook-up of the hydraulic brakes, which operate in 12-in. drums, is of the three-hose type, one for each front wheel and a third feeding both rear brakes.

The chassis is set low, with front springs flat when under normal load and the rear springs slightly cambered. All springs are fitted with rebound plates. The vertical-lift windshield is provided with a new form of double-arm lifter.

Desiderata That Underlie the Willys Designs

Primary objects underlying the design of the two Whippet and two Willys-Knight chassis, in order of their importance, are: safety, comfort, economy, and activity for the former, and safety, comfort, silence and endurance for the latter, according to A. J. Baker, chief engineer of the Willys-Overland Co. For safety the cars have been built low, particularly the four-cylinder Whippet, to give low center of gravity, and of relatively light weight, which helps acceleration and deceleration. All models have four-wheel brakes and clear-vision windshields.

Comfort is taken care of by the economical use of space allowed by the wheelbase, moderately roomy bodies, the fitting of shock-absorbers, and a new suspension for the four-cylinder engine that reduces the inherent vibration and takes care of torque reaction.

Economy is effected by rather high compression in a small engine and a moderately large rear-axle reduction. The increase in torque and maximum power in both the poppet-valve engines, together with the large rear-axle gear-ratio, provides the activity.

The big six-cylinder Willys-Knight now has a manifold like that of the smaller car of this type, and this has resulted in an increase of about 14 lb-ft. in torque and 8 or 9 hp., which allowed reduction of the gear-ratio to 4.7 to 1.0 without reducing the car's activity. A double-drop frame with lower center of gravity adds to the riding safety.

Franklins Made Roomier and More Powerful

Over-all dimensions of the Franklin bodies have been increased 2 in. in each direction to give more leg-room in the back compartment and more comfortable seating for three persons, said E. S. Marks, chief engineer of the company. The instrument board has been moved forward 2 in.

SCHEDULE OF SECTIONS MEETINGS

FEBRUARY

1—Buffalo Section—Gasoline; What It Was, What It Is, What It Will Be—A. Ludlow Clayden

2—Milwaukee Section—Mechanism of Lubrication—Robert E. Wilson

8—Chicago Section—High-Speed Ignition Systems and Breaker Systems—F. G. Shoemaker
Pennsylvania Section—What Has Research To Do With Manufacturing—J. H. Hunt

10—Indiana Section—Trend of the Industry as Reflected by the New York Show—T. J. Litle, Jr. Other prominent engineers will give 5 min. talks on the same subject
New England Section—The Electric Drive as a Motorcoach Transmission—Charles Froesch
Washington Section—Rubber and Its Uses—W. L. Holt

11—Southern California Section—Piston-Ring Symposium

17—Detroit Section—Electro-Deposition of Rubber—J. W. Schade and Dr. S. E. Sheppard
Metropolitan Section—Buses—R. N. Graham

with relation to the front seat and the gearshift base was moved ahead almost as much. Front and rear doors are 1½ in. wider. Front-corner pillars are narrower, giving better vision and increasing driving safety.

A 10-per cent increase in engine power has been accomplished by the use of a larger carbureter and a cast-aluminum square-section manifold that gives better charge distribution, easier starting and smoother operation. Crankshaft main bearings and crankpins have been increased in diameter. Life of the connecting-rod bearings has been increased by substituting a thin cast-in bearing for the thicker individually-cast bearing. This new bearing runs cooler, said Mr. Marks, because the aluminum of the connecting-rod is very close to the bearing-surface and the heat is dissipated more rapidly. Moreover, the bearing pressures are reduced and a very thin babbitt squeezes out less easily than a relatively thick babbitt.

The front wheels are balanced to give steadier and easier steering at high speeds, and ball-bearing knuckle-pins have been substituted for the plain-bearing type.

Keynote of the Stutz Is Safety

The safety keynote of the Stutz for 1927 is sounded in many minor but important refinements, asserted C. S. Crawford, the company's chief engineer. Safety glass is now used wherever glass is required. Weymann flexible closed bodies are available with the chassis and are 500 lb. lighter than composite or steel bodies of the same general over-all dimensions, and, as most of the reduction is in the superstructure, the center of gravity of the car is lowered still farther. The weight reduction also gives possible increase in acceleration and deceleration.

The hydrostatic brakes remain basically the same and eliminate flexible bands, rods and so forth. Experience has shown, said Mr. Crawford, that a brake having no servo action is the most dependable for a straight quick stop, as it produces no swerving action. The greatest problem has been to obtain a lining that possesses a higher coefficient of friction than linings regularly manufactured. This has been solved by a lining that has a coefficient of friction of from 0.65 to 0.70 and is as effective when wet as when dry. The fluid chambers have been reinforced to increase their life and dependability.

Other improvements include six-ply instead of four-ply tires, 10-lb. increase in engine compression, complete dual ignition with an independent coil for each set of eight spark-plugs, longer valve-stems and guides, and slightly larger cylinder-bore, which gives an engine output of 95 hp. at 3200 r.p.m.

Four-Speed Transmission in Paige-Detroit

An innovation this year is the use of a new type of four-speed transmission in the new eight-cylinder Paige-Detroit, G. C. Mather, chief engineer of the company, told the gathering. The transmission is a new development by the Warner Gear Co. and has two pairs of internal gears to provide third and fourth speeds. Gearshifting for first, second and reverse is in the conventional order, with a countershaft and sliding gears. The car can be driven indefinitely in third speed with no more inconvenience, noise or annoyance than with the customary three-speed transmission, Mr. Mather declared. Owing to a low axle-ratio of 5.25 to 1.00 on third, the car has better hill-climbing ability in this speed than drivers are accustomed to. Fourth speed has a high axle-ratio of 3.69 to 1.00, which enables very high speed to be maintained without the usual wear and tear on the engine. Economy tests just made show about 30-per cent better efficiency in fourth speed than in top speed with a three-speed transmission. This new transmission affords a possible 5 to 6 m.p.h. faster speed in fourth than the usual transmission. The new eight-cylinder car has a Lycoming engine with 3¼ x 4½-in. cylinders.

The three six-cylinder models have been changed slightly by increasing the cylinder bore to 2⅜ in., substituting interchangeable-type main-bearings and improving body lines, trimming and painting.

CRANKCASE-OIL DILUTION

Professor Fales Gives Informal Talk Before New England Section

D. A. Fales

The time-honored subject of crankcase-oil dilution was again discussed at the regular monthly meeting of the New England Section, which was held at the Hotel Buckminster, in Boston, on Jan. 19. Dean Abner Fales, assistant professor of automotive engineering at the Massachusetts Institute of Technology, who was the principal speaker of the evening, was introduced by Frank E. H. Johnson, service manager of the Noyes-Buick Co., who acted as chairman at the request of Section Chairman Glenn S. Whitham, who called the meeting to order.

In an informal talk, Professor Fales, after first reviewing the various causes of crankcase-oil dilution, took up each one in detail. Leakage in starting, he said, was due to poor pistons or fittings. Liquid fuel in the crankcase is caused by poor carburetion or by too much choking when using the self-starter. The presence of water he attributed to condensation or to chemical action of the products of combustion. Acid is formed by the combination of the sulphur in the fuel with the water in the crankcase when the fuel has been improperly blended. In a certain plant that was run on city gas enough acid was present in the cylinder to cause etching.

When benzol is used as a blend, continued Professor Fales, it sometimes contains by-products. If an engine has been poorly designed or is unseasoned, high spots on the cylinders wear off and the abrasive particles are carried away by the oil. To give sufficient lubrication, the viscosity times the speed divided by the load must be over a certain figure. The viscosity can be lowered by increasing the speed. Ricardo expressed the idea of lubricating by comparing it to the hydroplane action of a flat-bottom boat. With perfect lubrication there is no wear, but, when the lubrication is imperfect, it is comparable to a boat being pushed over sand. There is friction and dryness. To maintain the proper lubrication the speed must be of the proper rate and the piston must have sufficient clearance. Improper lubrication means greasy contact and rapid wear.

Water in the Crankcase

Water in the crankcase, said Professor Fales, is liable to freeze, and when it does the flow of oil may be blocked. When combined with sulphur, the water forms acid which etches the chains and the piston-pin. Black muck, sludge or carbonaceous matter occurs when the heat is great enough to cook the oil into carbon; but modern engines have little trouble on this account because of the more accurate fitting of the pistons and the cylinders. Aging of cylinders is beneficial, but requires too much space, so they are heat-treated to remove the strains. Cylinder castings are sometimes aged by rattling or shaking them.

The use of air-cleaners greatly reduces the trouble from dust. The effort to reduce crankcase-oil dilution has led to the use of castor-oil as a lubricant. For airplanes, castor-oil works well, but is not so satisfactory for automobiles. It is not soluble in gasoline, but, when cold, it is like vaseline and has great tenacity. It sticks to the surface and solidifies.

It has been found, continued Professor Fales, that if fresh oil is used in the crankcase it will become diluted, but if

a light oil is used to predilute the oil and a greater dilution then occurs, the excess is driven off by the heat. Fuel can be removed from crankcase oil by heating or vaporizing it or by blowing it out.

Dirt can be removed by filters, by the centrifuge, by which the heavy material is thrown out while the light remains in. Metallic particles are sometimes collected by passing the oil over a magnet before entering the oil-pump. Corrugated pockets, which act as oil-grooves, are sometimes used to trap the sludge, while in another kind of pocket the dirt is caught by settling. The pockets and the centrifuge clog up, however, and a cold chisel is sometimes necessary to clean them.

SYMPOSIUM ON TRAILERS

Southern California Section Discusses Evolution, Construction and Operation

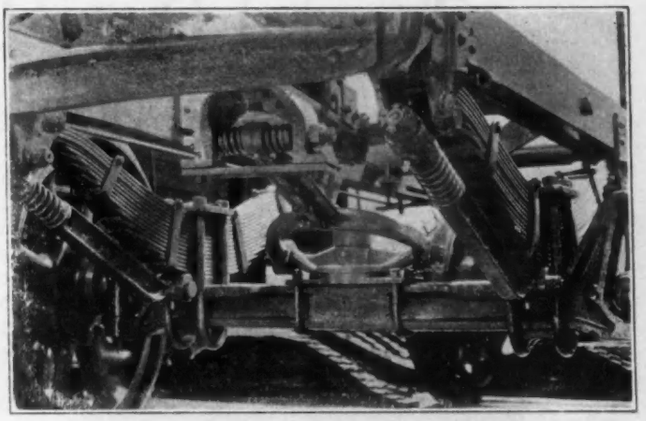
Trailers and the peculiar features of trailer operation was a topic that held the attention of the members and their guests and produced an animated discussion at the regular monthly meeting of the Southern California Section, which was held at the Los Angeles City Club, Los Angeles, on Jan. 14. Eugene Power, chairman of the Section, presided.

C. H. Mason, of the Hercules Trailer Mfg. Co., first stressed the importance of properly constructed four and six-wheel trailers in efficient automotive transportation. He was followed by J. L. Pike, of the Pike Auto & Trailer Works, who outlined the evolution of trailers from the days of horse-drawn wagons up to the present. Motion pictures that demonstrated some of the uses and abuses to which trailers are subject were shown by G. L. Stuewe, representing Mr. Knox, of the Utility Trailer Mfg. Co. In the absence of the author, Bruno Heymann, a description of a new and patented device for improving the intersteering ability of multiple-wheel vehicles of long wheelbase was read by Ethelbert Favary, who also added a written mathematical discussion of his own, illustrated with diagrams, showing when a truck can pull a trailer economically and when the use of a trailer is impracticable. When called on by Chairman Eugene Power, Mr. Brockway, of the Crown Motor Carriage Co.; F. H. Asbury, of the Asbury Truck Co.; Mr. Brush, of the Shell Oil Co.; Mr. Reinhard, of the Burr Creamery Co.; Mr. Sutherland of the Standard Oil Co.; Mr. Nevin of the Hammond Lumber Co.; and Mr. Adams, of the Southern California Telephone Co., also contributed interesting sidelights on the discussion.

Safety and Economy of Operation

In his talk on the importance of properly constructed trailers, Mr. Mason laid particular stress on safety and economy of operation and the preservation of the highways. Although the trailer does not have a power unit and other intricate parts that are necessary to a motor-truck, nevertheless, in many respects, it must be similarly constructed; it must be well balanced, so that the gross weight of the trailer and the load will be properly distributed over the different wheels, and the steering control must be constructed to allow free turning of the trailer, while at the same time preventing sideswaying and whipping during operation at any speed or over any kind of roadway. Many features that must be considered in its construction are minor details when compared with the construction as a whole, but they play a vital part in the stability, endurance and operation of the trailer.

Among the features contributing to its efficiency, said Mr. Mason, are ease of operation and sturdiness of construction. It must have a good steering-mechanism that will allow a short turning-radius without sacrificing the firm control of the front wheels that is necessary to eliminate whipping, yet must provide freedom of action. It must have good brakes, large axles and lightness, yet an ample factor of safety. Its life and maintenance depend upon stability of construction and upon the workmanship and materials employed. It must be capable of withstanding hard abuse, for it receives many harder road-shocks than does the pulling unit.



One Type of Rear Truck for a Six-Wheel Trailer
In This Design the Four Rear Wheels Are Carried on Two Axles Having Means for Equalization. The Four Rear Wheels in a Second Type Are Mounted on Individual Axles That Are Fastened into Single Rocker Beams with the Rocker Fulcrumed on One Main Rear Axle. In a Third Type the Four Rear Wheels Are Held between Two Rocker Beams on Each Side of the Trailer

New Intersteering Device

Reluctance to operate vehicles having a long wheelbase, wrote Mr. Heymann, is due to their lack of flexibility and difficulty of steering. When placed close and parallel to loading platforms or curbs, they cannot turn away, for the rear wheels and the rear end strike the platform or curb. They are in jeopardy when operated on narrow and short-turn grades, for the rear-turning movement tends to throw the rear end off the grade. They are also subject to increased whip or wabble. Mr. Heymann explained the use of a new intersteering device, which involves application of the principle of delayed turning-movement of the rear axle or rear wheels and is said to overcome these difficulties. The front axles or front wheels have a free turning-movement around their pivots of from 5 to 10 deg. toward either side of the longitudinal axis of the vehicle, during which the rear axle or wheels are rigidly locked to the frame perpendicular to its axis. When the free turning-movement of the front wheels is exceeded, the rear axle, through the action of rods, begins to turn also, but in the opposite direction, the latter movement being accelerated sufficiently so that, at the end of the turning movement, both axles possess the same degree of angularity to the axis of the frame, resulting in a decreased turning-radius for the vehicle. Whip or wabble is eliminated. By retarding the turning movement of the rear axle it is possible to operate successfully a number of vehicles in train formation, for each vehicle, properly spaced from the preceding one by a rigid draw-bar, will trail directly in its path and follow it in all its turning movements. The delayed turning-movement of the rear axle is also said to allow the removal of a vehicle from close or parallel contact with a loading platform or curb.

The Discussion

The discussion that followed the reading of the papers was largely devoted to the comparative slippage and wear of tires on four and six-wheel trucks and to the use of brakes on trailers. Other facts brought out were to the effect that the cost of maintenance of trucks was increased about 20 per cent by the use of trailers, but that the gross earnings are also increased from 25 to 100 per cent; and that tire mileage increases with use of trailers because of the lower speeds at which the equipment travels, which consequently reduces slippage and the grinding of the tires on the road.

General Pope Becomes Chief of Transportation Service

MEMBERS of the Society in general and particularly those interested in the military-transport phase of the Society's activities were much gratified by the promotion of Col. Francis H. Pope, of the Quartermaster Corps, to the grade of Brigadier General with assignment as Chief of the Transportation Service. This promotion followed the retirement of Brigadier-Gen. Moses G. Zalinski upon reaching his 64th birthday.

Photo by Harris & Ewing
BRIGADIER-GEN. FRANCIS H. POPE

General Pope was born at Fort Leavenworth, Kan., on May 7, 1876, and was graduated from the United States Military Academy in 1897. His connection with the motor-transport activities of the Army dates from March 20, 1916, when as a Captain, he was assigned to command a motor-truck company. Subsequently he was promoted to the rank of Major and commanded a motor-truck group of 30 companies, being transferred on May 21, 1917, to the Southern Department where he had charge of motor transportation for approximately 3 months. From Aug. 10, 1917, to July 15, 1918, General Pope served as Director of Motor Transport Service with the American Expeditionary Force in charge of the organization and operation of military transport, rising to the rank of Colonel. For approximately 1 year he served as Deputy Director of the Motor Transport Corps of the American Expeditionary Force and was transferred on July 29, 1919, to the office of Chief of the Motor Transport Corps in the City of Washington. Subsequently General Pope was appointed Chief of the Quartermaster Corps for the Fifth Corps Area and was stationed at Fort Hayes, Columbus, Ohio. He was made assistant to the Quartermaster General and transferred to the City of Washington last December.

General Pope was elected a Service Member of the Society in 1920. He took a prominent part in the organization of the Washington Section of the Society and was its first Vice-Chairman. In the following year, 1922, he was Chairman of that Section.

ABANDON THE POOR FARMS

THE Department of Agriculture reports the number of farms in the United States as approximately 6,400,000. Their products for 1925, exclusive of crops fed to livestock, are valued at $10,500,000,000. That indicates an average gross income of $1,700 per farm exclusive of livestock slaughtered and sold.

If we set aside the 1,000,000 farms on which the return is only $100, we find that the gross income for the remaining 5,400,000 farms is approximately $2,000. Government and other authorities, however, estimate that more than one-half of all the farm products of America is produced on 1,000,000 of the best farms. The average income on these good farms, in other words, is in excess of $5,000 per year. My own opinion is that this estimate is too low.

Think what a contribution to the wealth of the Nation would be made if we could put these 1,000,000 farmers now netting $100 per year in a way to earn the general farm average of $1,700 per year. Even the United States is not prosperous enough to ignore an addition to the purchasing power of its people of nearly $2,000,000,000 per year. And that sum, of course, is only a partial measure of the general benefit that would ensue from such a transfer. Chief among these is the effect the producing power of these farmers would have on the cost of food products.

I believe that if we could bring about this transfer at once it would not halt the upward tendency of food prices. But if the process of poor-farm abandonment is allowed to go along as heretofore, a process under which most of the farmers go into the cities in search of work, this upward tendency will be much more sharply defined. Today farms are fewer and fewer persons are engaged in farming than was the case 15 years ago. The farmers who fed 60,000,000 city folks in 1910 are feeding 82,000,000 today. By 1930 they will be required to feed 90,000,000 people in the urban communities.

To meet this constantly growing demand a steady supply of skilled labor is essential. The truth is that the United States cannot afford to lose the agricultural experience of these farmers now ekeing out a mere pittance on poor, arid and stony farms. We hear a considerable talk about excess production, but all economists know that there has never been a surplus of foodstuffs in the world except locally. As long as people can be found in the world who are hungry, we cannot truly say that a surplus of food exists. All that is lacking are transportation and the ability to pay, and so long as this condition remains uncorrected, we must admit that civilization to that extent has failed.—Guy Huston in Cleveland Union Trust Co.'s *Trade Winds*.

Cast Iron in Its Relation to the Automotive Industry

By E. J. Lowry[1]

Annual Meeting Paper *Illustrated with* Charts and Photographs

ABSTRACT

CAST iron is purchased on a basis of price instead of quality, according to the author, who says that this has depreciated the qualities of the material generally and caused engineers to look askance at its application. Combined with such factors is the influence of misinformation about cast iron that has been widely broadcast. Questions regarding the design of patterns and cheaper raw-materials have involved the foundrymen in controversial discussion concerning the influence of various elements to the detriment of the economic condition of the iron industry as well as that of the consumer of castings.

Due to the lessening of the consumption of cast iron, the foundry world has inaugurated research to better the quality of cast iron, not only through investigations of raw materials but also by improvement in melting practice. Although the accomplishment thus far attained has been small, the future outlook is that, due to the application of the results of research or by the use of alloys, the field for cast iron will become broadened. Then the engineer can obtain the material suitable for his needs and the foundryman will have a metal with the requisites suitable for foundry work.

The work of the metallurgists—microscopic, chemical and physical—has resulted in data which may help in overcoming previous prejudices. Some of the undesirable elements have been eliminated to overcome difficulties in casting, and yet this has been to the detriment of the physical qualities of cast iron; but when their proper relativity has been determined these elements will find their way back into the iron and better qualities will result.

The data presented tend to prove that true hardness is not measurable by any known test. Further, that the present hardness-test is not a function of machinability or of wear and that combined carbon bears little relation to any of these three factors. The governing features seem to be the forms of carbon, the structure of the iron and the quality of the materials used.

The method used in determining quality of material is that of dilatation. This test showed that the expansion of the casting is related to the expansion of the material used. It is felt that continual experimentation with this method will enlighten the many unanswerable questions which arise concerning cast iron at present.

CAST iron has become a material judged today solely by its analysis, approximate strength and hardness. Those dealing with it have forgotten the fundamental relationships of origin, melting practice and quality, factors which have been discarded for the seemingly urgent requisite, price. The cast-iron industry has become more or less stagnant during the last 10 years, due to the lack of knowledge the consumer and the engineer and designer have of the properties of its product. Price and design features have compelled the founder to use inferior raw-materials in the production of his castings and to resort to "tricks" in the art of molding to allow him to "get away" with castings from an intricate pattern. The result has been a depreciation in the physical properties of cast iron.

The engineer who has investigated cast iron has found that its physical properties do not meet his requirements and, with little thought of what might be done to increase these values in cast iron, he has taken the easiest course and changed to what he believes is a better material at a slightly increased cost. The answer to the question as to what could have been done with cast iron if that "slightly increased cost" had been added to its purchase price is debatable. The glaring lack of reliable information regarding cast iron, combined with the conflict in the opinions of those who know, is initially the cause of such debate. When people within their own profession cannot agree, those outside that profession will look askance at whatever result the insiders produce. This is true of the cast-iron industry. It has become the dog that everyone kicks at because it has had no stability either in its product or in its researches.

The engineer is not wholly without blame for the aspersions he throws upon cast iron. He really is not informed on the subject. He has collected a mass of information which held true in former days but which is obsolete today. His judgment is warped by the comparisons of "old" with the "new" cast-irons. He forgets that the cast-iron profession has advanced in the same proportion as his own. He should seek the new data and start again. But the engineer is not the only one who deserves criticism. The designer and the founder as well have been equally negligent. The designer is more or less a genius. He seeks to perfect an idea without due regard for cross-sectional differences and the impracticable conditions which arise in the foundry. The foundryman, in overcoming these difficulties, has changed the analysis or some other factor, thus disturbing the standards for wear and other qualities that, by right, cast iron should have. The chemist and the metallurgist also have been lax in working out the solution for the industry. They are far from being practical men. Their employers expect that the mystic power of chemistry will smooth the way; but, unfortunately, chemistry and physics alone will never be the panacea. It will only be by the combined efforts of the engineer, the designer, the foundryman, and the metallurgist that a solution will be reached. The chasms between the views of these professions are too wide at present for the reason that, when cast iron is thought of, it is principally as an immobile substance with some strength, a hardness and an analysis which gives a degree of machinability. Little do we know about the hardness of cast iron; much less about its machinability.

Because someone said that the way to make cast iron is according to analysis, everyone tried to play "follow the leader." To a great extent everyone is still in the same file. Later, another man decided that hardness is the thing and that fad started. Of course, the leader

[1] Metallurgist, Hickman, Williams & Co., Chicago.

was "stumped" at times and especially so after he had advocated that hardness and combined carbon went hand in hand. He soon found that they really do not, because at times a 0.40-per cent combined carbon would give him a soft casting and then again a hard one.

Peculiarities of Cast Iron

Cast iron is peculiar. Not enough thought and consideration have been given to it. Its very complexity is almost a Gibraltar-like barrier when one stops to consider the myriad practices, analyses and kinds of material that enter the making of similar castings in different foundries. There is not a man who could write down dogmatically just what two different foundries should do to produce good castings. Each foundry is a law unto itself, and study is required in the working out of a solution of the problems.

This paper was written to show a few of the properties of cast iron which have been forgotten, neglected or cast aside to the detriment of cast iron. No solution to the evolution of a perfect cast-iron has been given. At present, that would be impossible. There are hopes, however, when standards have been determined. The present day presents too many difficulties such as mystic practices, varying raw-materials, inconstant melting-practices, a multitude of molding conditions and the like. These difficulties must be overcome; then, a better cast-iron will result.

Present-day understanding of the constitution of cast iron is that it is composed of carbon, silicon, sulphur, phosphorus, and manganese. There is some comment to the effect that gases such as oxygen and nitrogen are present, but no tangible data. In fact, the oxygen theory of Johnson has been more or less exploded by the researches of the Bureau of Standards. The effect of nitrogen is still unknown, yet there may be something to it. Then again one hears of the growing use of alloys such as copper, chromium, nickel and molybdenum. And for what reason? The answer is still somewhat foggy. It is ensconced in the haze of debate and no one really knows the facts as yet. Nothing has so far been said of the iron which comprises the bulk, about 94 per cent, of the cast iron, nor does anyone even detail the forms of the carbons in cast iron.

It seems that interested persons do actually divide up carbons under the headings of total carbon, combined carbon and graphitic carbon, but it sometimes sounds peculiar to hear a discussion of these divisions. One foundryman claims that he is guided by the total carbon, while two others base their claims on combined carbon and graphitic carbon respectively. All three are attempting to attain the same end, hardness, if that means anything, and machinability. Strange to say, if all three founders produced an analysis in their irons that was similar in every respect, the chances are that the hardnesses and machinabilities of their products would be different. Or, if the hardnesses were the same, the machinabilities would vary. It is an abject situation.

Influence of Carbon

Regarding the other four well-known elements, their effects have been established definitely and the purchaser of castings sometimes has the temerity to specify them. Often, all the effects of these elements are not so certain. It all depends upon their relativity. No one can say just what will happen to a casting when the variable, carbon, creeps in and throws these four elements into chaos.

Undoubtedly we have been given the right fundamentals to work on, but we have taken too much for granted. We have neglected the fact that there is a definite analysis which prevents ready annealing of a casting in a mold. We have forgotten that some elements are more vital in this situation than others, and we have condemned these very elements as being harmful and tried to eliminate them from the iron. Hence, a new analysis appears which sets us the task of paying high prices for alloy irons to restore qualities which we have intentionally destroyed. We destroyed them because we did not know how to cope with the situation due to shrinkage or some other trouble which we believed they caused. This made us thoughtlessly increase the cost of manufacture of pig iron and, ultimately, to increase the cost of our castings; but we were no better off.

Our negligent actions did not cease at this point. Analysis, hardness and sometimes strength became the guides for quality cast-iron. As these guides crawled in, quality raw-materials slipped out. It would not have been so bad if foundrymen had taken advantage of cheaper and more economical materials such as briquetted borings and turnings or higher percentages of scrap in the mixtures. But instead of such extremes happening, the founder was forced to cut down on the scrap used in proportion to the pig iron and still the castings were inferior.

Use of Steel Scrap

The universal cry for steel in mixtures brought grief to the foundry trade until it learned how to use steel. Steel scrap accomplished a few purposes for the foundrymen of the world but its constant misuse has depreciated needed qualities in cast iron. There is a balance between the various materials entering a cast-iron mixture at which any one of the materials gives the best advantages.

With the advent of steel-scrap mixtures came the waning of charcoal irons. The initial cost appeared too great and the same hardness, strength and analysis could be attained by coke irons and steel scrap. Industries have learned, however, that the initial cost is not so important as the ultimate cost, and quality irons are finding their way back into the foundry. Why? In the days of the former cold-blast charcoal-irons, castings were made with higher percentages of scrap and carried lower percentages of silicon; they did not expand under heat, they did not crack, they wore famously well and shrinkage at points where unlike sections met was not prevalent. Was it a question of silicon, sulphur, phosphorus, or manganese? Experience does not point to these factors.

The old Diesel-engine cylinder-block carried a high percentage of phosphorus, with the manganese percentage running all over the lot and the sulphur following. The silicons used were hit-or-miss percentages. No, it does not seem to be the four major elements listed. It may have been the carbon; but not by percentage, because this element moved from 3.10 to 3.70 per cent. It was the form of the graphitic carbon, an almost fiber-like needle-structure that persisted in the casting from the pig-iron structure, if there were any relation to carbon and to the quality of the casting. But this was not the only feature that affected the casting; it was the quality of the iron that aided in the production of these old-time castings. This factor has never been given due consideration by the new school of industrial men.

The major point to remember in the production of a quality iron-base pig-iron is that it shall be smelted slowly, from easily reducible ores, and under good conditions. From such resulting pig irons, quality castings

will be made. It pays, ultimately, to use quality materials or to investigate materials that will mix and give a like result. By "quality materials," expensive brands of irons is not meant; the term applies to those materials which, under foundry conditions, will serve the purpose.

Prevalent Misinformation

One of the great needs in the foundry industry today is a correction of the misinformation which has either come out of the data of the past or out of the misconception of statements made by foundrymen and others. The situation is a difficult one to correct. The impossibility of the correlation of the experimental researches of contemporaries leads to confusion. Much greater is the confusion due to the translating of data from researches made in different periods of the foundry business. Added to this are the differing deductions from

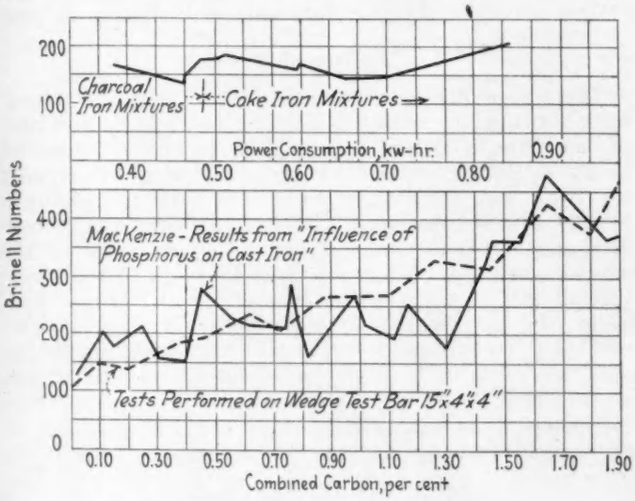


Fig. 1—Tests of Machinability

The Machining Was Done on an Electrically Driven Boring-Mill Performing the Cuts on Two Cylinder Bores. The Speed Was Maintained at 64 R.P.M.; the Feed Was 137 In. per Min. and the Cut Was 74.88 Ft. per Min. Two Cylinder-Blocks Were Selected from Each Cast, and the Power Consumed Was Observed To Check the Results. The Power Consumption Did Not Vary with the Brinell Hardness or the Combined-Carbon Content

any one investigation by different men. Take as an instance the celebrated work of West on cast iron. If one man wished to do so, he could prove readily that the strongest irons in this test were the cause of higher percentages of silicon, while another man could deduce that the lower percentages of sulphur were the cause of the increased strength or could even prove the contrary.

As a rule, when drawing conclusions from data, all the evidence is not taken into consideration. Hence, when a re-application of the test is made, failure and then condemnation result. Those not closely allied with the foundry industry have tried to set down certain facts, from researches, to apply in the purchase or the use of castings. This is an impossible predicament and those having such guides should be instructed carefully as to the limits of their use.

Some people still persist in the belief that chemical analysis tells the complete story of cast irons; but this is an unfortunate idea, because nothing is more misleading so far as quality is concerned. For example, in his 1902 published researches Keep states that "Silicon is more effectual as found in some irons than in others." Different properties were found in irons of like analyses in his experiments, which caused him to make this statement. Analysis of cast iron is but a guide for manufacturing operations.

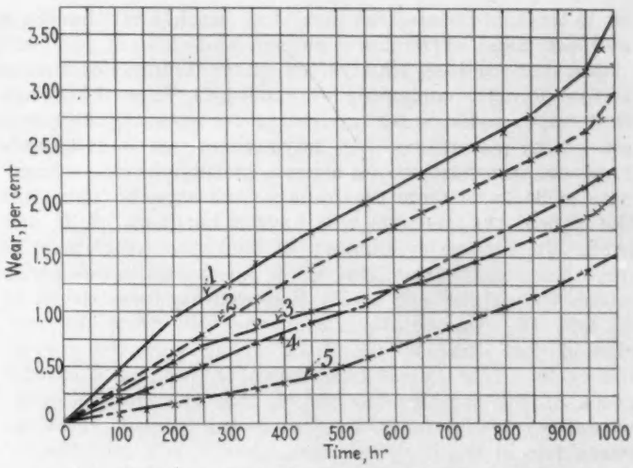


Fig. 2—Relation of Phosphorus Content to Wear

The Results Tend To Show That the Higher the Phosphorus Content Is, the Greater Is the Resistance to Wear. The Following Tabulation Is Self-Explanatory

Iron No.	1	2	3	4	5
Total Carbon, per cent	3.26	3.32	3.28	3.28	3.29
Combined Carbon, per cent	0.47	0.49	0.50	0.46	0.49
Silicon, per cent	2.10	2.10	2.14	2.10	2.12
Sulphur, per cent	0.091	0.085	0.087	0.091	0.091
Phosphorus, per cent	0.195	0.400	0.565	0.796	0.911
Manganese, per cent	0.55	0.58	0.56	0.59	0.55
Brinell Hardness	170	166	180	185	160

Hardness

Another subject which has been misleading engineers is the factor of hardness. Today in many instances, automobile plants are accepting castings on the basis of hardness specifications. The tooling operations are set up for definite hardness limits. Everything seems satisfactory until a casting comes along which tears down the tools. The hardness of the casting is within the specified limits and yet the machinabilities of the like hardnesses are different. It is difficult to understand just why this should be unless one is acquainted with the quality of the materials used in the making.

Engineers believe that hardness and combined carbon go hand in hand. Yet, in one of the largest automobile shops in the Country, there are series of combined-carbon hardness-analyses which show that, for a 0.49-per cent combined carbon, the Brinell hardness may vary from 140 to 190. Again, for a Brinell hardness of 170, the combined carbon varies from 0.42 to 0.68 per cent.

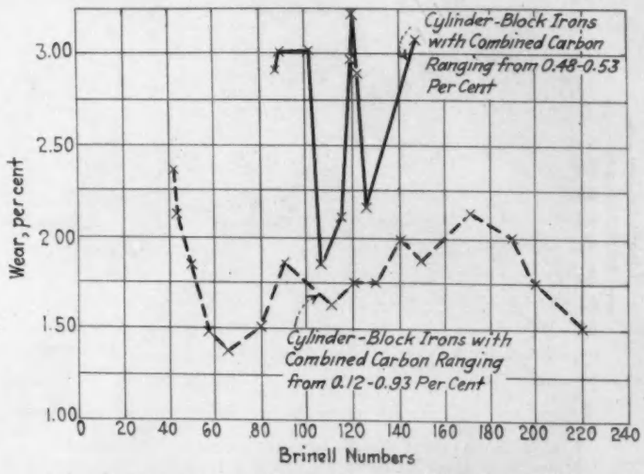

Cylinder-Block Irons with Combined Carbon Ranging from 0.48-0.53 Per Cent
Cylinder-Block Irons with Combined Carbon Ranging from 0.12-0.93 Per Cent
Wear, per cent
Brinell Numbers

Fig. 3—Relation of Brinell-Hardness Number to Wear

The Data Show Little or No Relation Between Wear, Combined Carbon and Brinell Hardness. The Materials Used in Making the Cast Iron, the Carbon Forms and, Possibly, a Third Unknown-Factor Seem To Be the Determinants

It is evident from this practical work that hardness and combined carbon are not correlated.

Another striking illustration of what hardness means is found in the annealing of castings. There is a shop that buys castings for annealing to permit subsequent machining-operations. It buys them on a Rockwell-hardness specification. It accepts castings having a hardness of 88 to 94 from the foundry and expects that after the anneal the castings will have a hardness of 85 and over. In the major number of the cases, the castings meet the specification, but there are many instances in which the original 88 to 94 Rockwell-hardness drops to 65 and 70. Immediately, everyone will draw the conclusion that there is something wrong with the annealing cycle. That is not true, however, because a careful check of the practice has shown that the low Rockwell-hardness castings may come out of the furnace right between two of the high readings. No, it is a condition of the iron which permits this phenomenon to take place. It is very much like three pieces of malleable iron which come out of the same pot; one with a white fracture, another with a partly turned fracture and the third with a completely malleableized fracture. All three pieces may have been side-by-side in the anneal, of identical analyses and yet made from different heats. All irons are not equally susceptible to heat. This is a point well worth remembering when hard bores which must withstand core annealing are desired in cylinder-blocks.

Wearing Quality

Practically everyone adheres to the principle that hardness is a requisite of wear. Yet there have been tests on cylinder-blocks which prove the opposite. The wear in these cylinder-blocks increased with the closeness of grain of the iron. The blocks were tested in a 75,000-mile run. This test checks experimental researches which tend to show that maximum wear is gained with an open grain and a combined-carbon content of about 0.20 per cent. This holds true not only in automobile work but in high-compression-cylinder work. Wear is also a function of carbon structure and to a small degree is based upon the matrix being pearlite.

The ability of a casting to resist wear is primarily a function of its analysis and its carbon structure. It is directly related to the amount of expansion under increase of temperature and the percentage of primary carbon present. As secondary carbon increases, so does the wear.

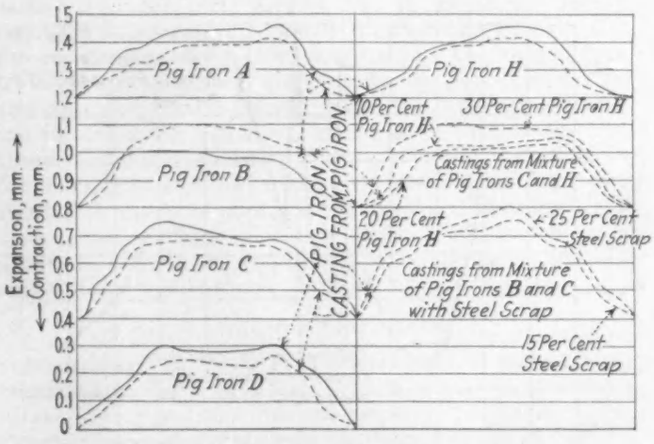

Expansion, mm. ↑ Contraction, mm. ↓
Pig Iron A
Pig Iron B
Pig Iron C
Pig Iron D
Pig Iron H
10 Per Cent Pig Iron H
30 Per Cent Pig Iron H
Castings from Mixture of Pig Irons C and H
20 Per Cent Pig Iron H
25 Per Cent Steel Scrap
Castings from Mixture of Pig Irons B and C with Steel Scrap
15 Per Cent Steel Scrap
PIG IRON CASTING FROM PIG IRON

Fig. 4—Dilatation Tests of the Various Cast-Irons

The Curves Have Been Reduced in Size and Only the General Characteristics Are Given. The Dark Full-Lines Are Those of the Pig Irons, and the Dotted Lines Are Those of the Castings Made from the Iron. A Difference Is Noted between the Amounts of Expansion of the Specimens. It Is Evident That the Expansion Takes Place More Readily at Lower Temperatures in Some Irons Than in Others

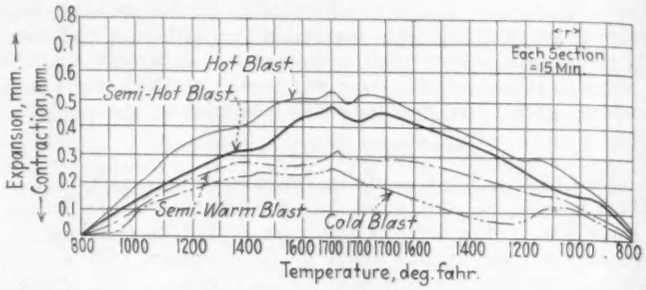


Fig. 5—Effect of Manufacturing Processes on Expansion and Contraction in Pig Irons

The Analyses Were Identical in Each Case. The Changes Noted Are Caused by Varying Grades of Ore Used in Manufacture as Well as by the Operation of the Furnace

Machinability

There is a misunderstanding of the term "machinability" as applied to cast iron. Engineers and consumers of cast iron translate machinability to mean degrees of hardness. There seems to be no direct relation between the two. For example, a block with a Brinell hardness of 600 can be machined, while a block with a Brinell hardness of 241 cannot; yet one with a hardness of 183 can be machined. There seems to be more to the structure of the iron in relation to machinability than hardness. As an instance, cylinder-blocks of like analyses but cast on different days had different machining qualities. Too little attention is paid to this factor and machine-shop costs increase almost unknowingly. These increases would more than offset the investigation of proper materials for the making of cast iron.

Influence of Phosphorus

Foundrymen as well as engineers have the feeling that phosphorus increases internal shrinkage in a casting. It does under the present methods of procedure, but it is not phosphorus alone that causes internal shrinkage; the cause is the relation silicon-carbon-phosphorus. These three elements give fluidity to the iron. The iron stays liquid too long at uneven sections in which the content of these elements is high. The result is that the smaller section solidifies and draws metal from the larger section. The gates or risers become choked and feeding stops. Hence, the shrinkage occurs. To run a higher percentage of phosphorus, the percentage of silicon should be lowered to get a quicker and more uniform-setting metal. Such practice will increase the ability of a casting to withstand wear.

Automobile work presents an anomaly in that the cylinder-blocks are made from irons low in phosphorus content, from 0.18 to 0.24 per cent, and the piston-rings are made from irons of higher phosphorus content, from 0.40 to 0.60 per cent. This situation needs some attention because these two parts of the engine are not of equal wearing-ability. The effect on either part may be that one wears out the other. In other words, sometimes a soft piece of metal will wear out a harder metal and then again vice versa, depending on their relation.

Listing these misconceptions could go on almost indefinitely because there has been little correlation between theory and practice. When the theory has been worked out, the final conclusions should not be drawn until practical demonstrations have proved the value of the work. Under such conditions, investigators would greatly enhance the worth of their researches. Further,

a practical explanation incorporated with the theoretical one might prove illuminating to those not trained in the metallurgical science.

Possibilities of Cast Iron

This paper has so far been concerned with the skepticism and poor application of the fundamentals of cast iron by those in the industry. The situation is not as black as it is painted but it could be better. And it is time that the cast-iron industry was given more thought and consideration. Price should always be kept in mind, but this should be evaluated in terms of the return in improved qualities of cast iron. This would enable the founder to better his product and spend some money on research, which, in turn, would repay the buyer of castings.

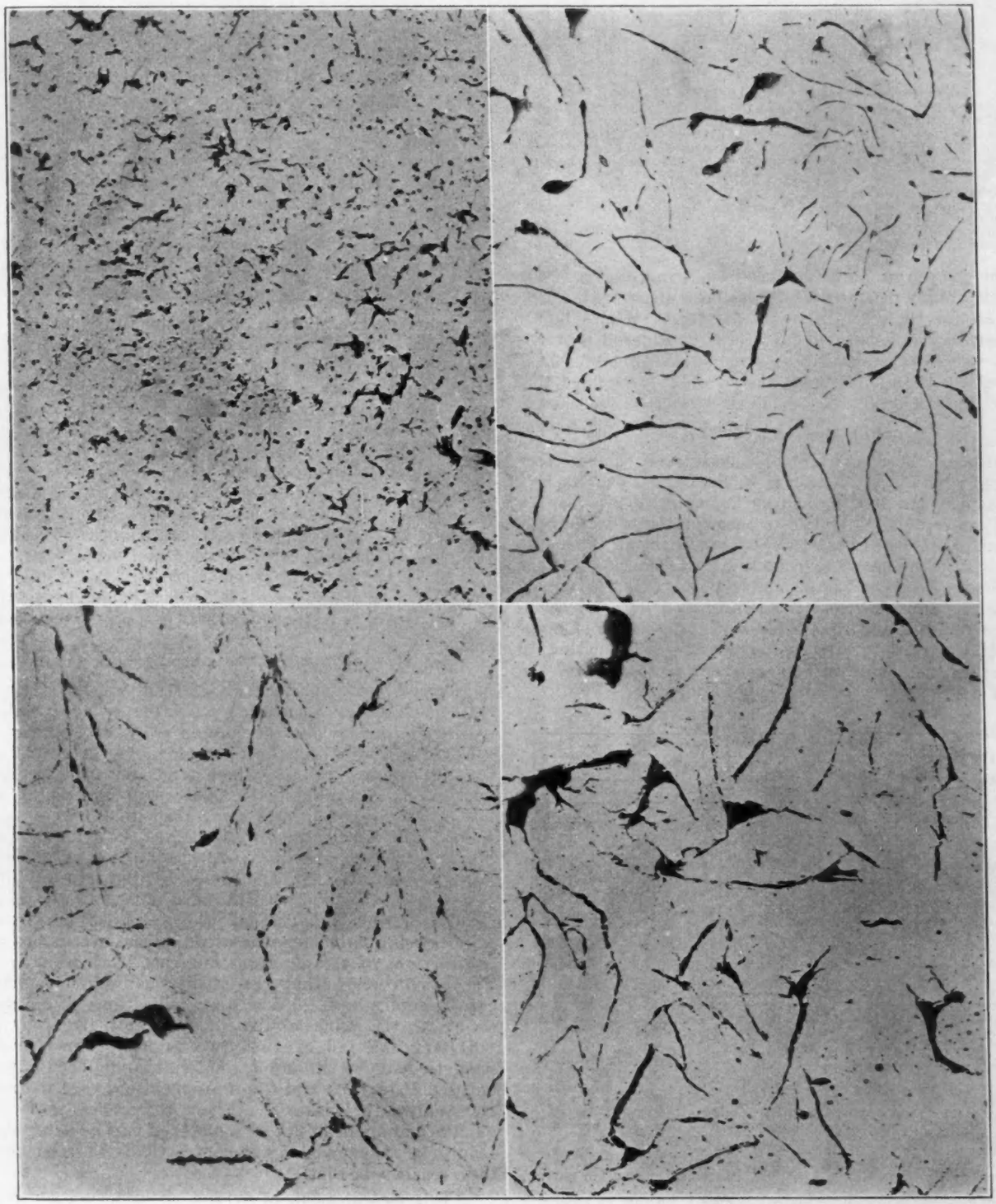


Fig. 6—Photomicrographs of Pig-Iron Structures
The Different Characteristics of the Structure of Pig Iron Are Evident. The View at the Upper Left Results from the Hot-Blast System; That at the Lower Left, the Semi-Warm Blast; That at the Upper Right, the Semi-Hot Blast; and That at the Lower Right, the Cold-Blast Method

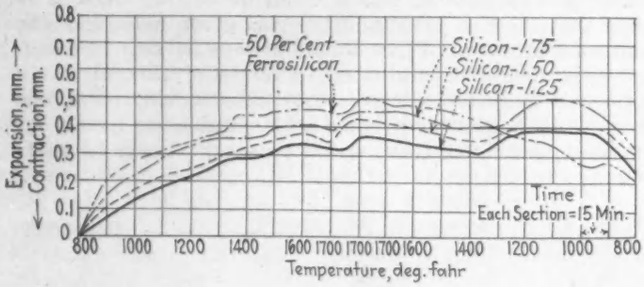


FIG. 7—EFFECT OF CHEMICAL ANALYSIS ON EXPANSION

The Effect of Silicon on Expansion Is Also Indicated, Because All the Other Elements Were Kept Constant. The Lower the Silicon Content Is, the Less the Expansion Will Be. The Expansion and Contraction for Three Silicon-Irons and a 50-Per Cent Ferrosilicon Are Shown. Aside from Differences in Silicon Content, the Composition of the Irons Was Identical, Being as Follows:

Total Carbon, per cent	3.92
Combined Carbon, per cent	0.45
Sulphur, per cent	0.016
Phosphorus, per cent	0.413
Manganese, per cent	0.36

The gray-iron industry has been progressing in research. Many new processes have been discovered. These are all for the perfection of cast iron. Where 30,000 lb. per sq. in. tensile strength was considered a strong iron, one is becoming accustomed to hearing of 50,000 lb. per sq. in. and, in some instances, it is claimed that upward of 60,000 lb. per sq. in. has been reached.

SUPERHEATING PROCESSES

Perhaps the most famous investigator along these lines of high-duty cast iron is E. Piwowarsky of Aachen, Germany. He has developed a patented process for superheating metal which is operable in any foundry practice. His claims are that, by superheating the metal, he destroys the germs or centers of graphitic formations which are inherent in the materials used in the cupola mixtures. Coincident with this process are the Thyssen-Emmel and the Wüst methods for the production of high-grade cast-irons by high-temperature cupola-melting in connection with revised cupola practice. These are the latest developments in cupola operations.

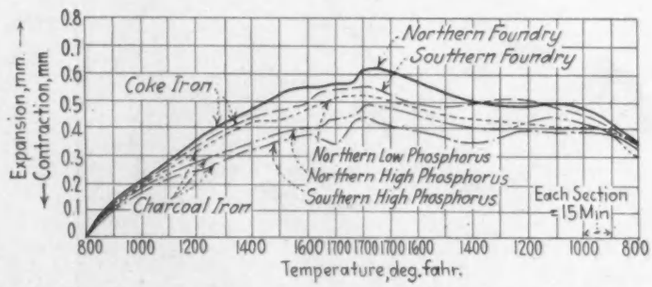


FIG. 8—EFFECT OF ORES AND FURNACE PRACTICE ON EXPANSION

The Influence of Phosphorus on the Expansion of an Iron Is Also Indicated. Curves for Two Coke-Irons and Three Carbon-Irons Are Reproduced. The Difference Between the Curve of the 1.25-Per Cent Silicon-Iron in Fig. 7 and the Curve for the Southern High-Phosphorus Iron in Fig. 8 Is Caused by Reheating. The Following Tabular Statement Is Self-Explanatory

	Coke Irons		Charcoal Irons		
Name	Northern Foundry	Southern Foundry	Northern Low Phosphorus	Northern High Phosphorus	Southern High Phosphorus
Total Carbon, per cent	3.900	3.920	3.940	3.930	3.920
Combined Carbon, per cent	0.420	0.410	0.430	0.460	0.450
Silicon, per cent	1.240	1.270	1.260	1.230	1.250
Sulphur, per cent	0.026	0.025	0.018	0.019	0.016
Phosphorus, per cent	0.850	0.860	0.190	0.420	0.413
Manganese, per cent	0.600	0.550	0.390	0.370	0.360

In this Country, Meehan, of Chattanooga, Tenn., has developed a calcium-silicide ladle-treated metal for high-test irons. He claims high strength combined with machinability. All these methods are worthy of study because they show that our present precepts for cast iron are not well founded and that cast irons may come to hold a more important place industrially than they do now.

The works of J. E. Bolton on carbon formations and J. T. MacKenzie on phosphorus throw interesting light upon the possibilities of cast iron, even as we now know it. These elements have been shown to hold newer positions by their investigators. They have been the most neglected and yet the most important elements of cast iron from the economic viewpoint. The present mode is to judge cast iron by silicon, which must be purchased from the blast furnace in one form or another, whereas, carbon is given free to the purchaser. In the case of phosphorus, the lower the content of this element is, the lower is the phosphorus content in the ores used and the more expensive becomes the blast-furnace operation.

ALLOYED CAST-IRON

Regarding the alloying of cast irons, the ultimate possibilities are yet unknown when nickel, chromium, molybdenum, and the like are used in cast iron. It is a positive fact, however, that these alloys are handicapped at present in giving their fullest virtues to cast iron. They are added with the intent to correct a condition rather than to lend quality to a casting. This is very different from their uses in the field of steels. What should be done first is to rectify the conditions existing in the present gray or chill-irons by a complete expose of the complexities. Then, with this knowledge in mind, the alloying metals could be added and beneficial results reaped. As it is, it is feared that a great percentage of these expensive alloys are used where equal effects could be reached by a better understanding of materials and cast irons.

DILATOMETRIC ANALYSIS

Physical and chemical analyses seem to be the favored methods of judging materials. Neither, however, is able to provide a complete description of quality. Only recently has there been brought to the attention of the foundry world a method which tends toward describing quality. It is a dilatometric analysis of materials. The first work ever performed along these lines was done by Keep. He called it a "shrinkage test" and judged analyses by the results. Unfortunately, the name he gave to his method did not fully detail the possibilities of the test. He was actually measuring contraction instead of shrinkage. The next work was executed by me. A Rockwell dilatometer was used and the expansions and contractions of the pig irons and cast irons were noted. The results show that the quality as well as analysis can be determined. There were indications which seem to attest the annealability of malleable iron.

During the fall of 1926 two famous French metallurgists, A. Portevin and P. Chevenard, published a paper entitled Principles and Chief Applications of Dilatometric Analysis of Material. Their researches show that quality and applicability of a material can be determined readily by its expansion and contraction. The conclusion they reached is that

> This measurement, of evident scientific importance, affects also industrial problems: the selection of materials forming the parts of heat-engines or refrigerating-machines.

The strength testing of cast irons must be given more

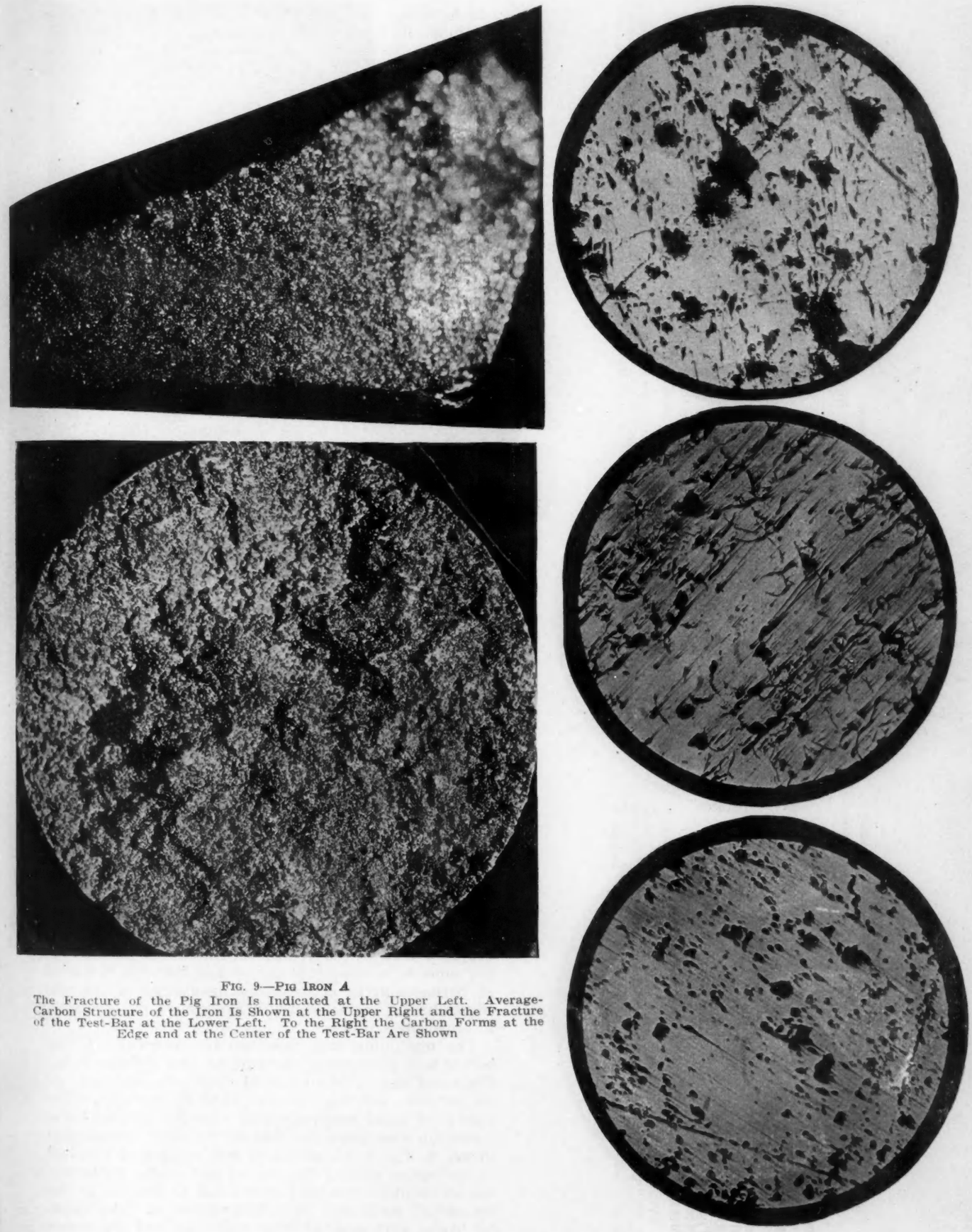


FIG. 9—PIG IRON *A*

The Fracture of the Pig Iron Is Indicated at the Upper Left. Average-Carbon Structure of the Iron Is Shown at the Upper Right and the Fracture of the Test-Bar at the Lower Left. To the Right the Carbon Forms at the Edge and at the Center of the Test-Bar Are Shown

TABLE 1—ANALYSES OF CUPOLA CHANGES CYLINDER CASTINGS[2]

Grade	Amount of Pig Iron, Per Cent	Analysis Charged			Analysis of Casting					
		Silicon	Sulphur	Phosphorus	Manganese	Total Carbon	Combined Carbon	Silicon	Sulphur	Phosphorus	Manganese	Nickel	Chromium
Pig Iron *A*	42.5	2.25	0.059	0.146	0.68	3.57	0.49	2.31	0.099	0.134	0.75	0.069	0.34
Pig Iron *B*	45.0	2.24	0.058	0.135	0.72	3.40	0.50	2.29	0.091	0.124	0.81	0.058	0.32
Pig Iron *C*	42.5	2.23	0.059	0.142	0.71	3.51	0.50	2.09	0.101	0.124	0.78	0.081	0.31
Pig Iron *D*	41.0	2.22	0.063	0.157	0.73	3.62	0.49	2.03	0.094	0.140	0.78	0.070	0.34
Mixture *E*	10 *H* 30 *C*	2.22	0.058	0.145	0.74	3.60	0.49	1.95	0.090	0.128	0.70	0.065	0.37
Mixture *F*	20 *H* 20 *C*	2.22	0.058	0.150	0.71	3.48	0.48	2.06	0.102	0.132	0.70	0.062	0.30
Mixture *G*	30 *H* 10 *C*	2.23	0.056	0.155	0.67	3.57	0.50	2.30	0.099	0.131	0.67	0.070	0.35
Pig Iron *H*	41.0	2.23	0.056	0.163	0.63	3.61	0.51	1.98	0.090	0.139	0.65	0.020	0.33
Mixture *J*	15 *B* 30 *C*	2.25	0.061	0.144	0.73	3.60	0.50	2.03	0.104	0.136	0.72	0.030	0.30
Mixture *K*	15 *B* 30 *C*	2.10	0.059	0.137	0.71	3.56	0.53	2.03	0.101	0.145	0.71	0.038	0.35

[2] The percentage of steel scrap remained at 15 per cent, except mixture *K*, which carried 25 per cent. The silvery iron used varied within 16 to 83 lb. per 1000 lb. Mayari pig-iron in small percentages was also added to the mixture and the high chromium was added in the ladle in the form of ferrochromium. Pig iron *H* is the charcoal iron, whereas the others are Central West coke-irons. The analyses charged into the cupola and those found in the castings are given in order to show that there was a certain amount of consistency in the melting and that the charges received about the same amount of oxidation.

deliberation. At present, the test-bar means little or nothing. It has no relation to the casting and yet engineers are basing their assumptions on data taken from such bars. The work of Rother, Elliot and others gives good information, but it often misleads the engineer into believing that cast iron is not all that it should be. It is hoped that with further research some correlation of the test-bar to the casting will be had.

Combine all of the foregoing with the diagram of Maurer and the work of Louis Predboeuf, entitled Results Obtained in the Improvement of Qualities in Cast Iron, and there is reason to believe that a better cast-iron will result to the satisfaction of the foundrymen as well as the engineers.

Presentation of Data

The charts and photomicrographs which follow are from an extended research of automobile cast-irons. The results were obtained from tests performed in various automobile plants. It was only with the kind cooperation of the executives and employes of these plants that these experiments were completed.

The test of most interest is that showing the difference in four brands of coke irons and one charcoal iron, varying the proportion of the latter from 10 per cent to a full charcoal-iron mixture. In the instance of the coke irons, the mixture contained only one brand at a time during the test. Hence, there is a comparison not only of various coke-irons but also of coke iron and charcoal. During the test, like analyses were obtained and also like Brinell hardnesses. It was thought best to cast test cylinder-blocks as well as test-bars, so that actual practical evidence could be shown. The analyses of the casts were performed in the foundry laboratory and later were checked by a commercial chemist. The samples were analyzed for 27 different constituents by the chemist. There seemed to be no appreciable difference in the rarer elements; therefore, they are not listed. The photomicrographic work was conducted on sections from the test-bars, taken at like positions so that the conditions presented in the pictures would be as nearly constant as possible.

The melting was performed in a cupola, using by-product coke for fuel. The cupola practice, as well as the foundry practice of the shop, was excellent. Care was taken to make sure that the metal would be as uniform as possible and that the pouring temperatures were within fair limits. Table 1 shows the analyses of the pig irons and mixtures charged and of the cylinder castings.

The next point of interest is that of the relation of combined carbon and hardness to machinability. It is supposed that, normally, like hardnesses should machine the same to a reasonable degree and that the variation of hardness gives a corresponding change to the machinability of irons. But this experiment did not seem to prove these beliefs.

The machining was done on an electrically driven boring-mill, performing the cuts on two cylinder-bores. The speed was maintained at 64 r.p.m.; the feed was 137 in. per min. and the cut was 74.88 ft. per min. The amount of metal removed varied with the cylinder but a correction was made for this in the final computation shown in Fig. 1. A recording wattmeter was attached to the motor driving the boring-mill. The wattmeter was so sensitive that hard spots could be detected as the boring-mill performed its cutting operation. Two cylinder-blocks were selected from each cast, and the power consumed was observed so as to check the results.

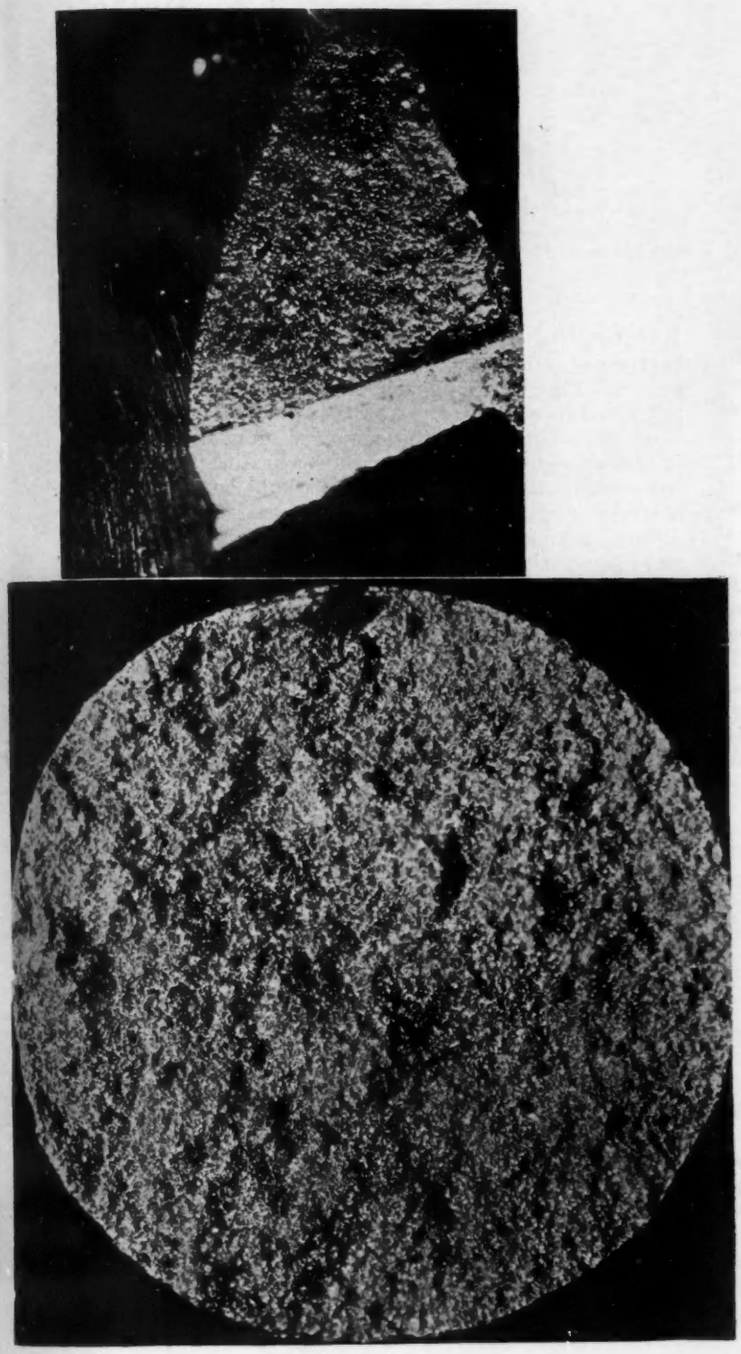


FIG. 10—PIG IRON *B*

The Fracture of the Pig Iron Is Indicated at the Upper Left. Average-Carbon Structure of the Iron Is Shown at the Upper Right and the Fracture of the Test-Bar at the Lower Left. To the Right the Carbon Forms at the Edge and at the Center of the Test-Bar Are Shown

It will be noticed, in Table 2 and in Fig. 1, that the power consumed did not vary with the Brinell hardness or the combined carbon. There seems to be no well-established relation between these factors. The Brinell hardness varied 61 points, the combined carbon varied 0.05 per cent and the machinability power-factor varied 0.295 kw-hr. Cylinders made from pig iron *A* and *D* seem to give like results, whereas the other mixtures change the aspect of the graph. For instance, pig iron *B*, showing a Brinell hardness of 146 with a power rate of 0.0615 kw-hr. and combined-carbon content of 0.50 per cent could be compared to pig iron *H* with a Brinell hardness of 166, and a combined-carbon content of 0.51 per cent but having a power rate of only 0.455 kw-hr. In every case, the charcoal-iron mixtures required less power to accomplish the machining operation. When the machinability of mixtures *J* and *K* are compared, it becomes evident that steel scrap increases the power consumed to perform like operations.

It is interesting to note here that two cylinder-blocks of like hardness to that of mixture *K* were annealed at a point where the Brinell hardness was not destroyed and the power consumed in machining dropped from 0.715 to 0.490 kw-hr. From this experiment, it has been believed that the carbon forms influence strain-hardness which impairs the machining quality of cast iron. In other words, the primary forms of carbon mixture of *H* give less strain-hardness than the mixture of primary forms with the secondary forms of *B*. Hence, the difference in machinability may be partly attributed to this feature.

Tests for Wear

The next phase which requires attention is that of wear. Table 3 gives the work performed at 1000 hr. The specimens were placed on a spindle rotating at 630 r.p.m., and were held at constant temperature by water-cooling. The specimens were "worn" by a brake-shoe of similar material which was attached to a lever-arm extending 3 ft. and carrying a 15-lb. weight at the end. Both the brake-shoe and the specimen were weighed at definite intervals to show the loss by wear. The results were checked by a tumbling-barrel method. Table 3 shows not only this feature but also weights per cubic inch and porosity.

It will be noticed in Table 3 that there is an appreciable difference in the wear of irons and that little or no correlation can be seen, either for hardness or combined carbon. Wear seems to be more or less governed by the carbon forms and perhaps by the pearlitic formation. So far as the analysis is concerned, this does not appear to be a tangible factor.

TABLE 3—TESTS FOR WEAR

Grade	Wear Test 1000 Hr., Per Cent	Weight Per Cu. In., Lb.	Porosity at 300 Lb. Per Sq. In. Pressure
Pig Iron *A*	3.2110	0.2583	3
Pig Iron *B*	2.9300	0.2552	5
Pig Iron *C*	3.1112	0.2566	2
Pig Iron *D*	2.9790	0.2582	1
Mixture *E*	2.8400	0.2592	0
Mixture *F*	2.1100	0.2592	0
Mixture *G*	2.1600	0.2571	0
Pig Iron *H*	1.8600	0.2587	0
Mixture *J*	3.0610	0.2584	0
Mixture *K*	3.0010	0.2593	0

During this test, the experiment shown in Fig. 2 was performed. This is self-explanatory and tends to show that the higher the phosphorus content is the greater is the resistance to wear. At the same time that the wear tests were conducted, the openness of grain was tested. It was expected that the closer the grain appeared to be, the greater the wearing quality would be. The results, however, were to the contrary. It was found that when a hard casting was worn against a soft piece, the maximum amount of wear occurred at the end of the first 100 hr.; but, at the end of 1000 hr., the soft piece had worn less than the harder one. The only seeming answer to this is the fact that the soft piece allows almost a colloidal shell to be formed by the slipping of the metal. When the final hardness-test was made after the wear-test had been performed, the surface had become almost glass-like. A further test showed that when a hard piece was put into contact with a piece of similar hardness, both pieces wore away readily. The analysis, except for combined carbon, was kept as constant as possible.

It was attempted to prove that the Brinell-hardness number gave an approximate value of wear. Fig. 3 explains readily that there is little or no relation between wear, combined carbon and Brinell hardness. It seems to be a matter of the materials used in making the cast iron, the carbon forms and, possibly, a third unknown-factor.

Table 3 shows the weight per cubic inch of the various cast irons tested. There appears to be some difference due to one factor or another. For example, for mixtures *J* and *K*, the weight of iron increases as the steel scrap increases. This should be expected, normally. The question of analysis does not seem to affect the results vitally where it is kept within limits. The effect of changes of material seems to carry the weight one way or the other.

Porosity

It is essential that the porosity of irons compared for weight should be inspected, and an apparatus was de-

TABLE 2—EFFECTS OF COMBINED CARBON AND BRINELL HARDNESS ON MACHINABILITY[3]

Grade	Combined Carbon, Per Cent	Brinell Hardness of the Cylinder	Hardness of Test-Bar			Transverse Strength, Lb. per Sq. In.	Machinability Power Consumed, Kw-Hr.
			Brinell	Rockwell	Scleroscope		
Pig Iron *A*	0.49	170	179-163	80-70	38-29	2,925	0.060
Pig Iron *B*	0.50	146	167-156	78-72	38-26	2,725	0.615
Pig Iron *C*	0.50	207	207-196	80-72	40-33	3,075	0.750
Pig Iron *D*	0.49	170	179-163	78-70	38-31	2,850	0.060
Mixture *E*	0.49	181	217-202	84-80	40-35	3,525	0.545
Mixture *F*	0.48	174	196-187	83-80	39-36	3,575	0.515
Mixture *G*	0.50	185	223-217	91-88	41-39	3,350	0.540
Pig Iron *H*	0.51	166	196-196	81-77	38-36	3,275	0.455
Mixture *J*	0.50	161	196-163	85-70	37-30	2,950	0.600
Mixture *K*	0.53	149	217-196	87-80	43-33	3,350	0.715

[3] It is apparent that the combined carbon varies but 0.05 per cent while the Brinell-hardness number varies 58 points. This affords a true realization that the hardnesses of cast irons are not related to combined carbon. Fig. 1 offers further proof of this comparison; it shows that within a range of 25 points in the Brinell number, there is a likelihood of a difference of 0.90 points of combined carbon as shown by the full line. There does not even seem to be a relation between these two factors when they are taken from the same wedge-block as shown by the dotted line. Therefore, the conclusion that hardness and combined carbon have little direct relation is drawn.

FIG. 11—PIG IRON C

The Fracture of the Pig Iron Is Indicated at the Upper Left. Average-Carbon Structure of the Iron Is Shown at the Upper Right and the Fracture of the Test-Bar at the Lower Left. To the Right the Carbon Forms at the Edge and at the Center of the Test-Bar Are Shown

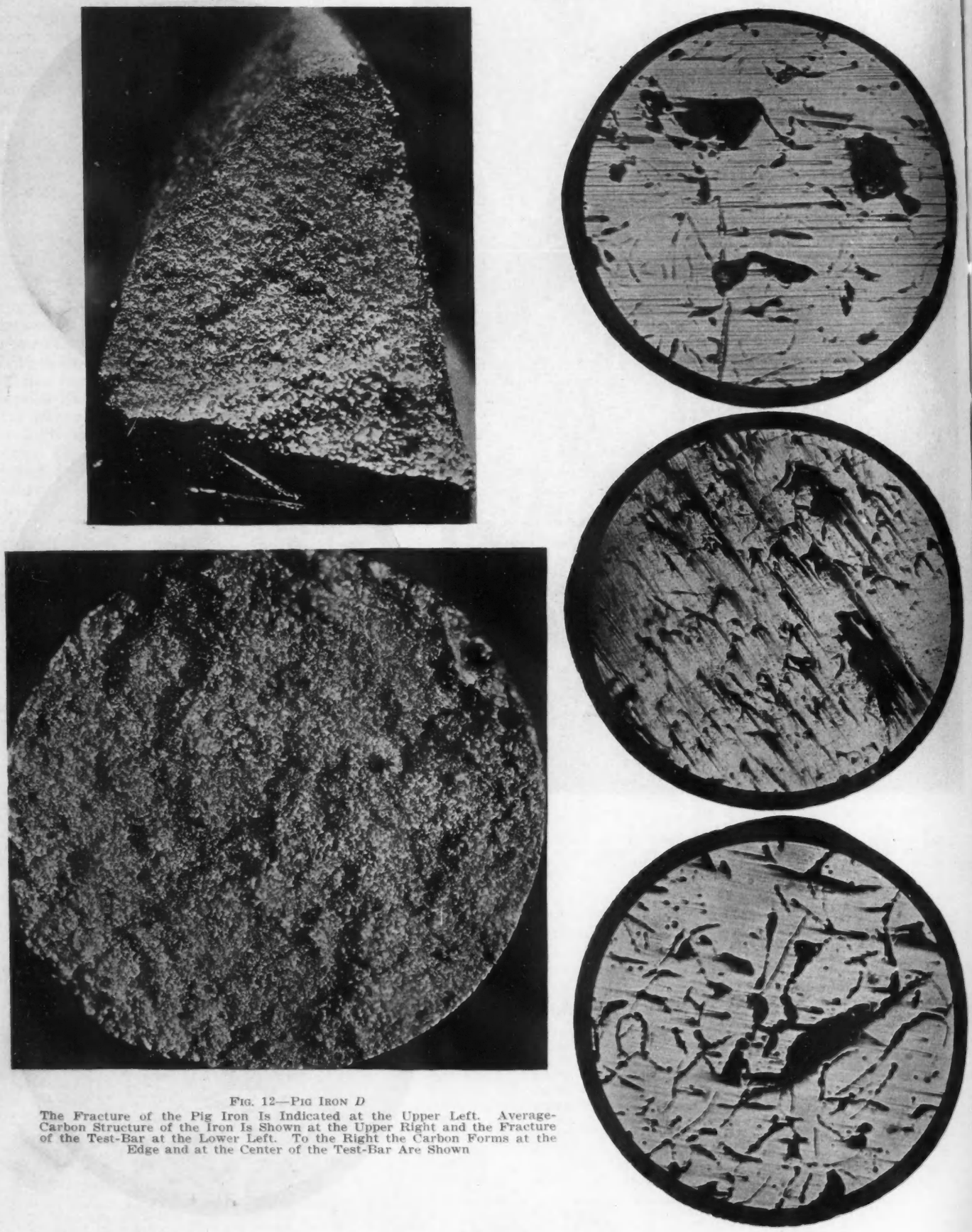


FIG. 12—PIG IRON *D*

The Fracture of the Pig Iron Is Indicated at the Upper Left. Average-Carbon Structure of the Iron Is Shown at the Upper Right and the Fracture of the Test-Bar at the Lower Left. To the Right the Carbon Forms at the Edge and at the Center of the Test-Bar Are Shown

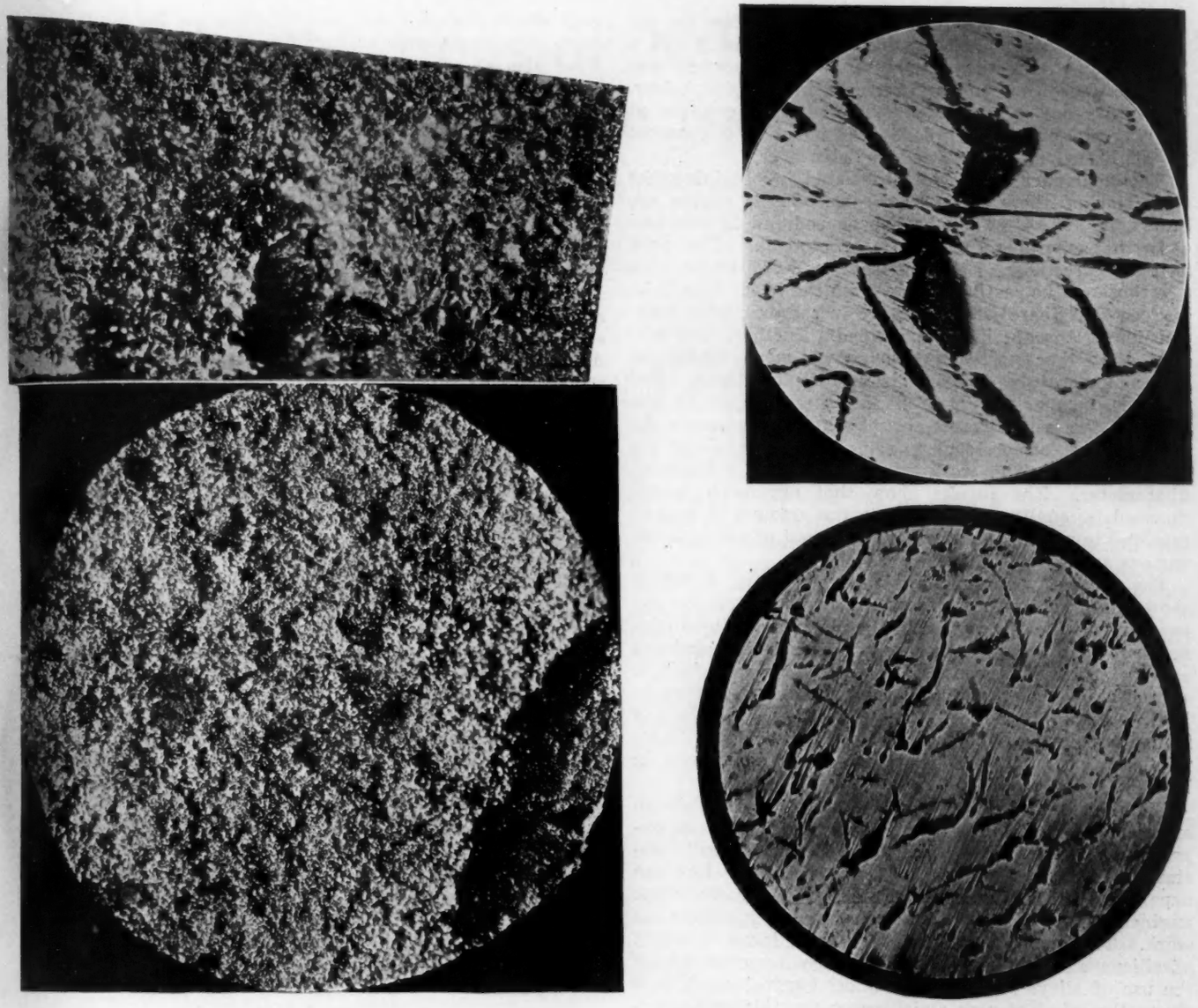


FIG. 13—PIG IRON *H*

The Fracture of the Pig Iron Is Indicated at the Upper Left. Average-Carbon Structure of the Iron Is Shown at the Upper Right and the Fracture of the Test-Bar at the Lower Left. To the Right the Carbon Forms at the Edge and at the Center of the Test-Bar Are Shown

vised to test this phase. It consisted of a holder for the specimen, a gage on either side of the specimen and a pressure-gage for the compressor. The specimen was threaded on either end and screwed into a pipe holder. The difference in pressure registered on the gages at varying stages was recorded. The effect at a pressure of 300 lb. per sq. in. is noted in Table 3.

The final part of the test consisted in obtaining the dilatation of the various cast-irons. These curves are shown in Fig. 4. They have been reduced in size and only the general characteristics are given. The dark full-lines are those of the pig irons, and the dotted lines are those of the castings made from the iron. It will be noticed that there is a difference in the amounts of expansion of the specimens examined. Further, it is evident that the expansion takes place more readily at lower temperatures in some irons than in others. For example, comparing pig iron *H* with pig iron *C*, the curve of the latter travels abruptly upward, whereas the curve of the former tends to slope off before taking the final evolution. This work was performed on a Rockwell dilatometer. The results show that expansion is influenced by quality, which affects the amount of energy required to put into solution or throw out of solution the various substances in cast irons.

The foregoing statement is proved by Fig. 5, which shows the effect of manufacturing processes on the expansion and the contraction in the pig irons. The analyses were identical in each case. The changes noted are caused by varying grades of ores used in manufacture as well as by the operation of the furnace. Referring to Fig. 4, it will be noticed that the influence of the pig irons goes through the cupola into the castings. Photomicroscopic structures of these pig irons are shown in Fig. 6.

Fig. 7 is included to show the effect of analysis on expansion, and it illustrates the effect of silicon on expansion because all the other elements were kept constant. The lower the silicon content is, the less the expansion will be, is the conclusion to be drawn. The engineer may be interested in this because it affects his work. The foundryman can work with lower contents of silicon and obtain his machinability requirement by the use of alloys which do not affect expansion. Fig. 8 shows the effect of ores and furnace practice on the expansion of an iron, together with the influence of phosphorus. The difference between the curve of the 1.25-per cent silicon iron in Fig. 7 and the curve for the Southern high-phosphorus iron in Fig. 8 is caused by reheating. This also shows that the dilatometer can be used to measure growth in cast irons.

Structural Differences

To show the comparative structural-differences in the castings made from the pig iron, photomicrographs of pig irons *A*, *B*, *C*, *D*, and *H* are reproduced as Figs. 9, 10, 11, 12, and 13. These pictures show the fracture of the pig iron in the upper left corner with the average-carbon structure of the iron in the upper right corner. In the lower left corner is the fracture of the test-bar and, to the right, are pictures of the carbon forms at the edge and at the center of the test-bar. There is a marked difference in the uniformity of the fracture and also of the carbon structure from *A* to *H*. The effect of the pig iron on this structure is evident. Where secondary carbons appear in the pig iron they seem to carry through to the casting and, likewise, with the primary-carbon form. The differences in machinability, hardness and expansion can be partly attributed to these apparent variations.

Summary

From the data obtained, the conclusions are that

(1) The price of cast iron governs its purchase, in most instances, instead of the quality

(2) The misinformation regarding cast irons has caused unfortunate circumstances to surround its application

(3) There is too little authentic information regarding the elements in cast iron

(4) The Brinell-hardness test does not actually indicate hardness, combined carbon, wear, or machinability

(5) The quality of the raw materials affects these factors

(6) The quality of the raw materials appears in the casting as well as carbon formations found in the raw materials

(7) Dilatation shows quality, analysis to a certain extent and expansion

(8) The expansion of the raw materials affects the resulting product

(9) Wearing quality and machinability are induced by quality materials

DOOR-TO-DOOR COLLECTION AND DELIVERY

VARIOUS forms of direct freight-delivery have been maintained in the United States for many years. At many points the railroads offer a collection-and-delivery service through the medium of trap cars with varying restrictions as to minimum weights and gross revenue. This service is ordinarily free. Lighterage is had at various points, and in one instance a freight tunnel, operated by an independent company, is used as a medium. Sub-stations have apparently been the result of compromise; the railroads would not extend a service to the merchant's door but would operate numerous stations, so that his haul might be shortened, or rather so that he, because of equalized or shorter hauls, would give the interested line a greater share of his freight shipments for towns and cities that were reached by one or more competing lines of railroad.

A system whereby all less-than-carload shipments could be picked up and delivered by the rail carrier, or some agency under its direct supervision, would decrease tremendously the investment in railroad terminals because, first, less space would be required and, second, the terminals could be located on cheaper land, as well as at points more convenient and economical for the assembling and dispatching of trains.—From an address by F. C. Horner before the Interstate Commerce Commission.

Applications of X-Rays in the Automotive Industry

By GEORGE L. CLARK[1], ROBERT H. ABORN[1] AND ELMER W. BRUGMANN[1]

ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPHS AND DIAGRAM

ABSTRACT

A resume of X-ray science and experimental results regarding practical applications to the examination of automotive materials is presented by the authors, the main divisions of the subject being (*a*) X-rays; (*b*) radiography, or industrial diagnosis, being an application of the differential absorption of X-rays by matter; (*c*) the ultimate structures of materials; (*d*) metals and alloys; and (*e*) the constitution and structure of other automotive materials in relation to their practical behavior.

The nature and the relationship of X-rays to light, the properties of X-rays which can be utilized practically, and production, including X-ray tubes, are discussed in division (*a*). The detection of imperfections in castings, the development of improved casting-technique by X-rays, the substitution of castings for forgings and X-ray examination of rubber tires, valves and the like are treated in division (*b*).

X-rays and crystals are analyzed in division (*c*) and the information obtainable from X-ray data regarding structural composition includes whether it is crystalline or amorphous; single crystal or aggregate; its crystal lattice-structure and dimensions; purity; chemical identity as to whether compound, mixture, adsorption complex, or solid solution. The data obtainable also apply to grain size, internal strain, uniformity of composition, chemical changes, and the differentiation of good and bad materials.

In division (*d*), the ultimate crystalline structure of the pure metals and the alloys used in the automotive industry, such as brasses, bronzes, steels, alloy high-speed steels, aluminous alloys, and the like, is considered, and the effects of fabrication as determined by X-ray diffraction are discussed in relation to cast metals, to rolled and drawn metals such as hot-rolled and cold-rolled sheets and to heat-treatment and its effect upon preferred orientation of grains, strain and grain size. Some practical studies of commercial automotive metals are cited for cast steel and the X-ray determination of its proper annealing regarding the structure of welds and the comparison of various methods of welding from the viewpoint of X-ray structure, for forming steel such as that suitable for radiator construction and X-ray determination as to whether it is satisfactory or unsatisfactory, for drawing steel-wire, and for case-hardened metals and their wearing qualities. Steel suitable for electrical purposes such as the construction of transformers and the relation of ultimate structures to magnetic hysteresis-loss are considered also, as well as the electrodeposited metals and the determination of desired electrodeposition conditions from X-ray structures. The materials discussed in division (*e*) include rubber; rubber fillers, with particular reference to carbon black; asbestos; the textile fibers such as cotton, flax, ramie, jute, sisal, hemp, rayon, silk, and wool; spark-plug porcelain; lubricants and X-ray indications of the mechanism of lubrication; and paints, varnishes, waxes, shellacs, and the like.

THE newest phase of the 31-year-old science of X-rays is its application to the practical problems of industry. X-ray radiation now constitutes a most promising tool which must be taken into account in the research and in the control laboratories of a long list of industries manufacturing almost every imaginable commodity. Because the automotive industry is concerned with so many different kinds of material it constitutes a particularly fertile field for the service of this new tool which, except for medical applications has been until recently, more or less a curiosity in the academic laboratories of physics and chemistry. This paper is concerned with a rapid survey of automotive applications resulting from pioneer experiments largely made in the chemical engineering laboratory of the Massachusetts Institute of Technology, primarily for the purpose of illustrating future possibilities. It will become obvious that each of the topics considered is a subject for an entire book[2] or for a greatly expanded paper.

X-RAYS

Concerning their nature, X-rays are electromagnetic vibrations in every way similar to those of ordinary visible light except that the average wave-length is only about 1/6000 as great as that of yellow light. In the electromagnetic spectrum are to be found, therefore, several types of radiation, all of which are fundamentally alike except in wave-length. The ranges in Ångström units are stated in Table 1.

The simple facts of the fundamental mutual similarity of electromagnetic waves and of the essential difference only in wave-length suggest immediately the general practical properties and the uses than can be made of X-ray radiation as compared with ordinary light. Since their wave-lengths λ are so much shorter, or their frequencies ν greater, inasmuch as $\lambda = c/\nu$ where c is the velocity of light, X-rays can be expected to penetrate materials that are opaque to light and to be intimately related to a far finer subdivision of matter than is possible for light waves. Even under the ultra-microscope, the examination of matter with the aid of visible light-

TABLE 1—WAVE-LENGTH RANGES

	Ångström Units[3]
Milliken Cosmic Rays	0.00040 to 0.00067
X-Rays from Radioactive Elements	0.01 to 1.40
Ultraviolet Rays	136 to 3,900
X-Rays	0.06 to 1,019
Visible Rays	3,900 to 7,700
Infra-Red Rays	7,700 to 4×10^6
Solar Radiation That Reaches the Earth	2,960 to 53,000
Hertzian, or Radio Waves	1×10^6 to 3×10^{14}
Electric Waves	3×10^{14} to 35×10^{16}

[3] One Ångström Unit = 0.0000001 cm. (1 cm. = 0.3937 in.)

[1] Department of chemical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

[2] See Applied X-Rays, by G. L. Clark.

FIG. 1—SPECIMEN OF IRON
The Structure of the Specimen As Observed by the Eye, Natural Size Is Shown. The Iron Was Etched To Show the Grains

rays can reach only a definite limit of size which is still far removed from that of the ultimate constituents. The ultra-violet microscope lately so successfully developed by Lucas[4] discloses a fine structure that appears perfectly homogeneous under visible light-rays, but here again a limit is reached. Beyond this, X-rays are able to take the investigator on to the ultimate molecules and atoms, even on to the planetary universe within the atom, if he but interprets his information properly; the reason lying in the fact that in solid crystalline matter the spacings of the ultimate particles of mass, which can be ascertained from density, the molecular weight and the mass of the hydrogen atom, are of the same order of magnitude as the wave length of the X-rays, namely, 10^{-8} cm. (1 cm. = 0.3937 in.)

As to their generation, X-rays are emitted whenever matter is bombarded by cathode rays; in other words, the sudden stoppage of swiftly moving electrons by the atoms of matter is accompanied by the generation of X-rays. In addition to this process, primary rays will themselves generate, under certain conditions, secondary X-rays upon being absorbed in matter. The essential parts of an X-ray generating apparatus are, therefore, a source of electrons proceeding from a cathode, which is a hot-wire filament in the Coolidge-type tube, a target or anti-cathode or anode in the path of the cathode-ray stream and a means of applying a potential difference between the cathode and the target which will accelerate the electrons to the requisite velocity during passage across the intervening space.

A complete description of all the properties of X-rays is impossible here. The following tabulation, essentially in the chronological order of discovery, will suffice. X-rays, then, are:

[4] See American Institute of Mining and Metallurgical Engineers Pamphlet No. 1576-C.

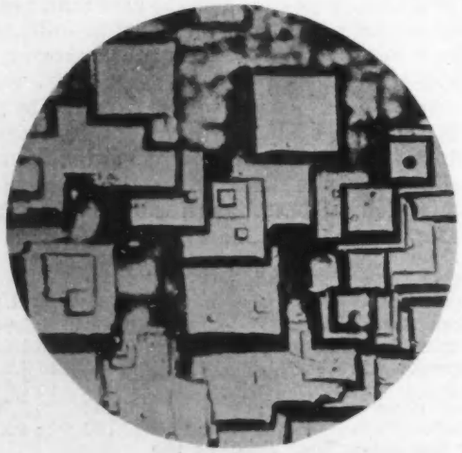


FIG. 2—PHOTOMICROGRAPH OF THE IRON SPECIMEN OF FIG. 1
The Magnification of 800 Diameters Makes Evident the Details of the Structure. Each of the Grains Still Comprises Thousands of the Ultimate Iron-Atoms

(1) Invisible and pass through space without transference of matter
(2) Propagated in straight lines
(3) Unaffected by electric or magnetic fields; hence, non-electrical in nature
(4) Reflected, diffracted, refracted, and polarized just as light
(5) Propagated with a velocity of 30,000,000,000 cm. per sec. (186,300 miles per sec.), as is light
(6) Transverse electromagnetic vibrations
(7) Of an average wave-length 1/6000 as great as that of yellow light, or 1×10^{-8} cm. (1 cm. = 0.3937 in.)
(8) Produced by the impact of cathode rays upon matter
(9) Capable of blackening a photographic plate

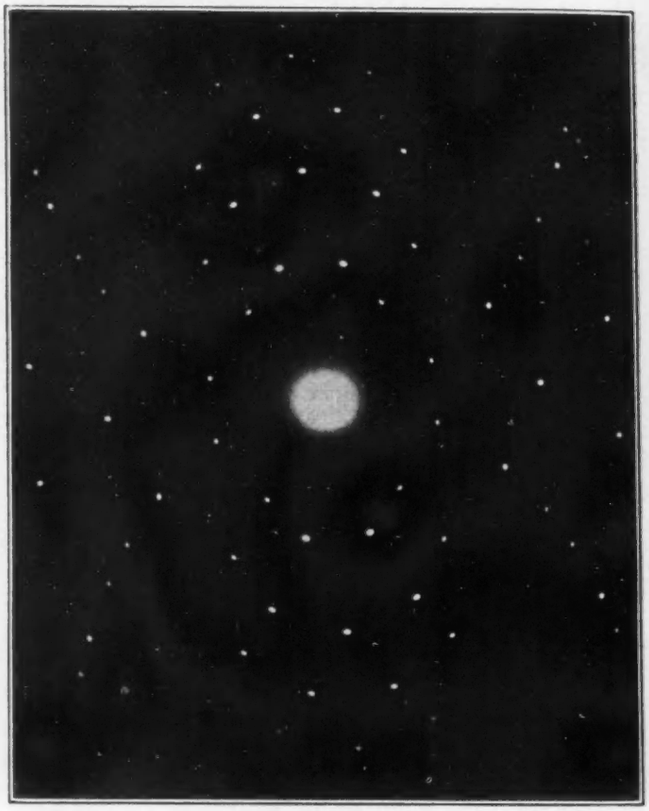


FIG. 3—X-RAY PHOTOGRAPH OR LAUE DIAGRAM OF A SINGLE IRON-CRYSTAL
When X-Rays Are Defined by Pinholes and Pass Through a Grain of Iron, They Are Diffracted by the Iron-Crystal Grating and Produce the Diagram Shown. Each of the Spots Corresponds to the Reflection of X-Rays of a Definite Wave-Length by One Set of Parallel Planes in the Crystal

(10) Capable of producing fluorescence and phosphorescence in some substances and of coloring some stones and minerals
(11) Able to ionize gases and to influence the electrical properties of liquids and solids
(12) Differentially absorbed by matter
(13) Able to liberate photoelectrons
(14) Capable of acting photochemically, activating catalysts in some cases, and flocculating colloids
(15) Able to stimulate or kill living matter
(16) Emitted in a continuous spectrum, the short wave-length limit of which is determined only by the voltage on the tube
(17) Emitted also with a line spectrum characteristic of the chemical elements in the anti-cathode
(18) Found to have spectra that are characteristic of the chemical elements and of three kinds: emission, absorption, and ionization

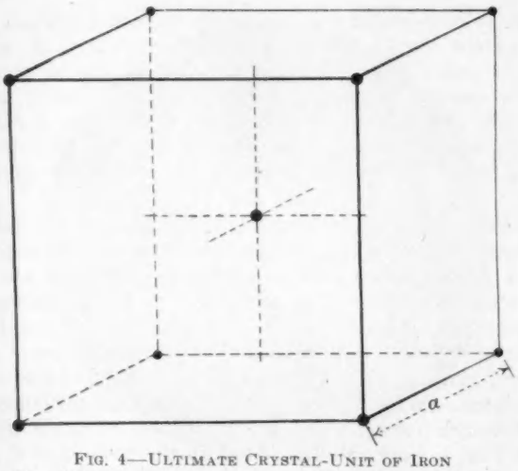


FIG. 4—ULTIMATE CRYSTAL-UNIT OF IRON
The Ultimate Crystal of Iron Is a Cube with One Atom at Each Corner and One Atom at the Center. This Minute Unit-Cell Is Multiplied in All Directions To Form the Visible Crystal

(19) Diffracted by crystals acting as gratings in accordance with the fundamental equation $n\lambda = 2d\sin\Theta$, to which a correction for refraction must be applied for very accurate work
(20) Diffracted by optical gratings at very small glancing angles
(21) Found to act in interference and related phenomena as waves; but in other phenomena as discrete quanta of energy which can be scattered by single electrons

In automotive applications we are concerned primarily with the properties of differential absorption in matter, blackening of a photographic plate and the diffraction by crystalline matter acting as a grating. These refer to radiography, or the examination of materials for gross defects from "shadow pictures," and to the study of the ultimate constitution or fine structure of these materials from characteristic diffraction-patterns.

RADIOGRAPHY AND DIAGNOSIS

Although X-rays, because of their short wave-lengths, are much more able to penetrate matter than is ordinary light, still they are differently absorbed by different substances; that is, all materials are not equally transparent to X-rays. These facts are the basis of the science of radiography. Broadly defined, the experimental technique consists in passing a beam of X-rays through the object to be examined and, by a fluorescent screen or photographic plate, recording the varying intensities of the emergent beam and thus obtaining a shadow picture of the interior of the object. Probably the first practical uses of X-rays were of a radiographic nature, and radiography today is a most useful tool to the medical and the industrial diagnosticians.

In the discovery and location of internal defects of the human body, radiography has become indispensable. The use of X-rays to examine fractured bones preparatory to setting, to study conditions of the teeth as an index to subsequent treatment and to locate bullets, swallowed pins and the like, has become so routine that everyone is acquainted with it. Not so well known, perhaps, are the uses of X-rays in the diagnosis of tumors, incipient tuberculosis of the lungs and joints, diseases of the alimentary tract, stones in the kidney and the gall bladder, and diseases of the liver and the pelvic organs.

The application of X-rays to the determination of defects and internal conditions in industrial materials is more recent than their use in medical diagnosis. Extensive radiographic tests on metals have been made at the Watertown Arsenal. In England, the use of X-rays in studying coal for inclusions of slate and the like has been suggested. There have been almost innumerable miscellaneous applications of radiography in examining finished products.

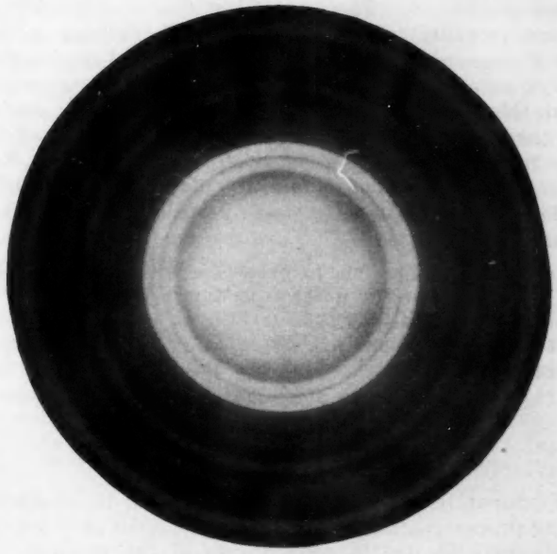


FIG. 6—PINHOLE DIAGRAM OF IRON AGGREGATE
This Complete Diagram Consists of a Series of Concentric Uniformly Intense Rings. The Grains of the Specimen Are in Disorder

X-RAY EXAMINATION OF METAL CASTINGS AND DEFECTS REVEALED

The use of radiographic examination of metal castings is aimed at two general results. One of these is the development of a casting technique that will assure the production of as large a percentage of castings free from serious defects as is possible. The other is the determination of the internal soundness of the one particular casting under examination. In the development of foundry technique, castings made in a certain way are

FIG. 5—X-RAY SPECTRUM FOR IRON CRYSTALS
The Spectrum Is for an Aggregate of Iron Crystals from Wire, Forming a Characteristic Diffraction-Pattern. The Beam of X-Rays of Single Wave-Length Is Defined by Slits and Is Diffracted by the Very Small Crystals Heaped Together in an Entirely Disordered Fashion

examined and the typical defects are discovered. The technique then is changed to eliminate such defects, typical castings made by the new technique are examined, other changes in technique are made if necessary and so on. In this way it has been possible to effect a material increase in the percentage of sound castings and, since radiographic examination is both expensive and time-consuming, this procedure probably is the most economical way in which radiography can be used. It does not assure perfection, however, since even an improved technique may occasionally give imperfect results. Moreover, very few castings are made at present with such a carefully developed technique. Hence, in those cases in which failure of the piece would result in a financial loss greater than the cost of the examination or in loss of life, it is of course the wise and economical thing to examine each individual piece for internal defects. The increasing use of high-pressure-steam installations, high-pressure oil-cracking systems, aerial transportation, and other industrial developments offers many instances in which such tests are not only desirable but often necessary. For example, castings in the high-pressure Edgar powerplant of the Edison Electric Illuminating Co. of Boston, at Weymouth, Mass., were all radiographed before acceptance and installation.

The defects that usually are revealed by radiographic examination are

(1) Gas cavities due to gases liberated from the hot metal and to gases from the mold
(2) Sand inclusions
(3) Slag inclusions
(4) Pipe cavities
(5) Porosity due to small gas-cavities and to small shrinkage-cavities
(6) Cracks
(7) Metal segregations

Fortunately, most of these defects can be avoided by using proper casting-technique; some, such as cracks and pipes, may be due to poor design of the casting. The exact identification of the particular type of imperfection cannot be made by rule, but results from long experience. Thus, depending upon the angle of the imperfection relative to the plane of a photographic plate, the same type may appear vastly different.

Many automotive applications of radiography suggest themselves in addition to the great field of castings and the great service of X-rays in making possible the wide and safe use of castings where forgings are now employed. Armatures in generators, molded insulation around metal parts, small metal-tubing, entire carbureters in place which may be functioning unsatisfactorily, welds, valves, soldered joints, spark-plugs, the bonding between cord or fabric and rubber in tires, insulated wire, and airplane frames, all these can be examined for interior soundness or for determination of the cause of unsatisfactory behavior without destruction or dismantling of the specimen. Here again the chief value of the X-ray method is in the establishment of a manufacturing technique that may assure a dependable product.

Ultimate Structures of Materials

Although radiography, depending as it does upon the different densities and absorbing powers for X-rays of materials opaque to ordinary light, is a signal achievement, X-rays can be used in a far more fundamental and ultimate sense in the examination of materials because of the fact that the wave-lengths are of the same order as the distance between the atoms in crystalline solids. Finely ruled lines on glass or metal diffract light but, except under the very special condition of an extremely small angle of incidence, these optical gratings are too coarse for X-ray diffraction. In crystal, nature provides gratings that are able to diffract X-rays in definite ways characteristic of the distance between the crystal planes upon which atoms lie in orderly arrangement.

To illustrate the information provided by crystal diffraction, the following illustrations should be compared: Fig. 1 shows an unenlarged photograph of a strip of iron etched to show the grains. Under a high-power microscope, one having a magnification of 800 to 1, the far more detailed structure of Fig. 2 is obtained. Each of these grains still comprises thousands of the ultimate iron-atoms. When X-rays are defined by pinholes and pass through a grain of iron, such as one of those appearing in Fig. 1, they are diffracted by the iron-crystal grating and produce the diagram shown in Fig. 3. All the photographs in this paper are unretouched. Some of the detail of the original negatives is, of course, lost in the reproductions. Each of the spots of Fig. 3 corresponds to reflection of X-rays of a definite wave-length by one set of parallel planes in the crystal in accordance with the equation $n\lambda = 2d\sin\Theta$, where d is the distance between the parallel atom-bearing planes; λ, the wave length; n, the order of reflection; and 2Θ is the angle of reflection measured from the position of the spot. Properly interpreted, the meaning is that the ultimate crystal of iron is a cube with an atom at each corner and one atom in the center, the edge length being 2.86 Augström units. This minute unit-cell, shown in Fig. 4, is simply multiplied in all directions to form the visible crystal.

Fig. 3 is a typical diagram for a single crystal or grain of iron. If a fine powder or aggregate of iron is used as the specimen, it is still possible to obtain a characteristic diffraction-pattern of iron as shown in Fig. 5. The beam of X-rays of single wave-length is defined by slits and is diffracted by the very small crystals heaped together in an entirely disordered fashion. The probability exists that enough of the grains will be turned at just the right angle with respect to the beam of X-rays so that many will cooperate to produce each diffraction line. A complete diagram would be a series of concentric uniformly intense rings, as shown in Fig. 6. Finally, there is an intermediate state between the single crystal and the chaotic aggregate of small crystals; namely, one in which the small crystals are lined up in a definite fashion with respect to some common direction. Such "fibering" can be produced by mechanically working a chaotic aggregate; that is, by rolling, drawing into a wire and the like. Fig. 7 is a typical fiber-diagram for a cast-steel bar pulled at 1200 deg. fahr. and showing symmetrical intensity-maxima instead of the complete circles of Fig. 6. Properly interpreted, the meaning of this diagram is that face diagonals of all the unit cubic-crystal cells of iron in the wire, as indicated in Fig. 4, are turned approximately parallel to the axis of the wire.

Information from X-Ray Data

We have seen that there are four different X-ray diagrams for the same iron, which illustrates the versatility of the X-ray diffraction-method and the different types of information obtainable from X-ray data. These can be enumerated briefly as follows:

(1) Crystalline or amorphous; if amorphous, the material produces only general blackening of a photographic plate or, at most, a very broad diffuse ring

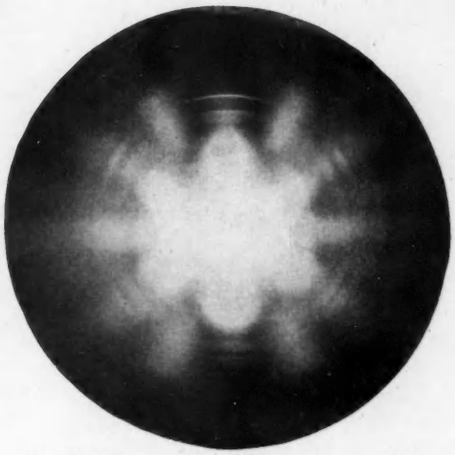


FIG. 7—TYPICAL FIBER-DIAGRAM OF A CAST-STEEL BAR
This Is an X-Ray Pattern Showing the Characteristic Fibering Produced by Pulling at 1200 Deg. Fahr. It Evidences Symmetrical Intensity-Maxima Instead of the Complete Circles of Fig. 6

(2) Single crystal or aggregate of small crystal grains
(3) Random or fibered aggregate
(4) Lattice structure and dimension; for example. iron, body-centered cubic, $d_{100} = 2.86$
(5) Purity; that is, the presence or absence of extraneous spectrum lines and the like
(6) Chemical identity; that is, whether a compound, a mixture, an adsorption complex, a solid solution, or the like
(7) Grain size
(8) Internal strain
(9) Chemical changes; for example, the gradual absorption of oxygen at the double bonds of unsaturated organic compounds
(10) Differentiation between good and bad materials from the foregoing viewpoints

In determining the grain size (7) use is made of the property of X-rays whereby a beam passing through a single grain produces a Laue pattern of definite symmetry as shown in Fig. 3. As the grains become smaller, the beam must pass through a larger and larger number in a given thickness of specimen. The diffraction spots become smaller and more numerous and the symmetry of the diagram is lost. Finally, a powder or aggregate is reached which produces the continuous uniform rings shown in Fig. 6. As the particle size becomes still smaller than 10^{-6} cm. (1 cm. = 0.3937 in.) in diameter, these rings become proportionally wider. Hence, a measurement of line-width enables an accurate calculation of grain or of particle size down to the extreme dispersion of colloidal particles. When the grains are larger than 10^{-3} cm. (1 cm. = 0.3937 in.), individual spots begin to appear, the size and number of which are an indication of grain size in this range.

Apart from fibering produced by mechanical deformations, the crystal planes can be bent or distorted and thus be under strain. This is evidenced on X-ray diagrams very sensitively by asterism striations or radial streaks extending from the center. The great problem of heat-treatment of metals is to relieve this condition; heat-treatment can, therefore, be excellently controlled by the X-ray diagrams.

The last of the uses listed above is, after all, the industrial X-ray method. Invariably it is found that there is a distinct difference in one or more of the enumerated ultimate properties determined from X-ray data, between two specimens of the same product, one of which satisfactorily meets the test of practical utility and the other of which fails. The X-ray method of research and control points the way directly to perfect quality. It is for this reason, perhaps, that it is not altogether welcomed except by those industrial companies that strive for the highest quality as desirable from both the altruistic and the business viewpoints.

Fig. 8 shows the multiple diffraction-apparatus with which we obtained the various types of diffraction photograph. On this apparatus, 18 exposures are made simultaneously from one X-ray tube having its long axis vertical in the center of the upper cylinder.

THE CONSTITUTION OF METALS AND OF ALLOYS

The greatest single field for the application of research, testing and manufacturing control-methods in the automotive industry by X-rays is unquestionably that of metals; (*a*) the examination of the gross structure for defects, by radiography, (*b*) the determination of the fundamental lattice-structures and atomic arrangements of the crystals of which all metals and alloys are constituted and (*c*) the detection and estimation of the effects of mechanical and of heat-treatment, grain size and other attributes. We are now concerned with the second of these types of information but, because of the magnitude of the subject, only brief mention can be made here of a very few of the developments in the analysis of constitution.

Referring to the pure metals, the majority of the metallic elements have been subjected to X-ray analysis. Most of these crystallize in the face-centered system, examples of which are the ductile metals such as silver,

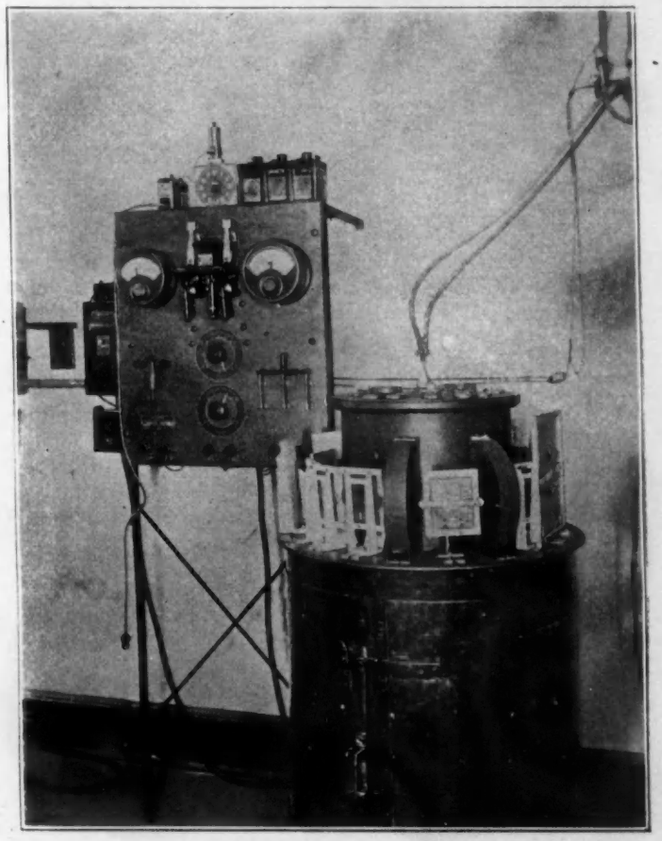


FIG. 8—MULTIPLE DIFFRACTION-APPARATUS
The Various Types of Diffraction Photograph Presented Herewith Were Obtained with This Apparatus, 18 Exposures Being Made Simultaneously from One X-Ray Tube Having Its Long Axis Vertical in the Center of the Upper Cylinder

FIG. 9—COMPARATIVE "POWDER" SPECTRA OF PURE COPPER AND BRASS
This Illustrates the X-Ray Analysis of Alloys and Shows the Difference in Spacing between the Pure Copper in the Upper Band and the 80-20 Brass in the Lower Band, the Brass Being a Solid Solution of 20 Per Cent of Zinc in 80 Per Cent of Copper

copper, aluminum, gold, and iron; in the body-centered cubic system, examples of which are the brittle metals such as tungsten, chromium, and α-iron; and in the hexagonal close-packed system, such as zinc and magnesium. Representatives also exist in the tetrahedral-cubic, such as gray tin; the rhombohedral, such as bismuth, arsenic and antimony; the double body-centered and the face-centered tetragonal systems, being respectively white tin and indium; and in complex cubic structures such as manganese. Several of the metallic elements crystallize in more than one crystallographic system, each representing a stable arrangement of the atoms in the crystal unit over a definite temperature-range. The most interesting of these is, of course, iron with its four allotropes. X-ray analysis of the crystalline forms has led to the identification shown in Table 2.

TABLE 2—X-RAY ANALYSIS OF CRYSTALLINE FORMS OF IRON WITH ITS FOUR ALLOTROPES

Modification	Magnetic Properties	Temperature Range		Lattice Type	Unit Cell Edge-Length, Angström Units	Number of Atoms Per Unit
		Deg. Cent.	Deg. Fahr.			
α	+	Below 800	Below 1,472	Body-Centered Cubic	2.855	2
β	—	800 to 900	1,472 to 1,652	Body-Centered Cubic	2.900 at 800 Deg. Cent. (1,472 Deg. Fahr.)	2
γ	—	900 to 1,400	1,652 to 2,552	Face Centered	3.630 at 1,100 Deg. Cent. (2,012 Deg. Fahr.)	4
δ	+	Above 1,400	Above 2,552	Body-Centered Cubic	2.930 at 1,425 Deg. Cent. (2,597 Deg. Fahr.)	2

New modifications of manganese and chromium have been discovered recently by the X-ray crystal-spectra.

ALLOYS

The study of alloys by thermal, microscopic and electrical conductivity methods has resulted in contradictions in numerous systems so that these methods do not suffice to determine completely the equilibrium diagrams and the structures of alloys. Supplementary X-ray studies are, therefore, essential. Even though these applications to the science of metals are in their very beginning, the achievements are already noteworthy.

In a series of alloys ranging from pure-component *A* to pure-component *B*, the X-rays show the number of crystal types involved at the temperature of investigation. These types are solid solutions of *A* in *B*, of *B* in *A* or of one or the other in inter-metallic compounds, definite inter-metallic compounds and mixtures producing superposed diffraction-patterns. All changes under heat-treatment can be followed in terms of the constituents, once they have been identified by their X-ray diffraction-patterns.

Fig. 9 shows comparative "powder" spectra of pure copper and brass containing 80 per cent of copper and 20 per cent of zinc. The pattern of lines in both cases is that of the face-centered cubic lattice of copper but, for the brass, all the lines are shifted closer to the zero position, which indicates an expansion of the original lattice by the substitution of zinc for copper atoms. Incidentally, it is this 80-20 brass that resists corrosion more effectively than brasses of other constitutions.

While several pairs of metals form a continuous series of solid solutions, brass forms solid solutions only up to about 38 per cent of zinc. Owen and Preston and Jette, Westgren and Phragmen have made X-ray examinations of the β or body-centered cubic, the γ or rhombohedral or complex cubic containing 52 atoms and the δ, ε and η

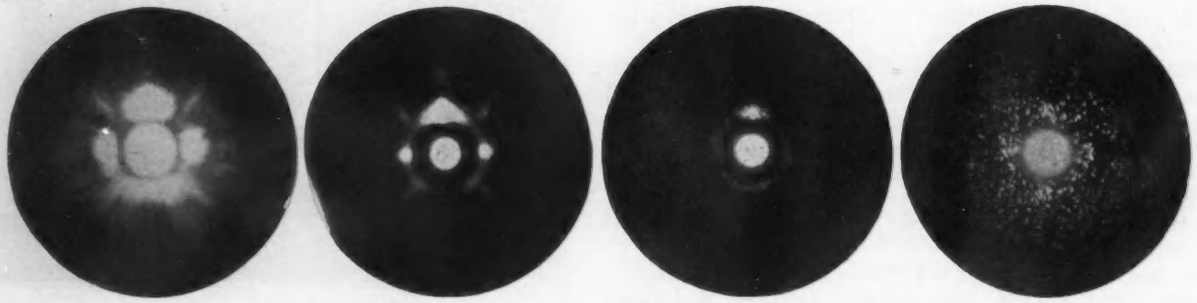


FIG. 10—SHEET-STEEL DIFFRACTION-PATTERNS
The Patterns Were Obtained with Ordinary Low-Carbon Sheet-Steel after Hot and after Cold-Rolling. The Hot-Rolled-Steel Pattern Appears at the Extreme Left and the Cold-Rolled-Steel to the Right of It. The Two Views at the Right Illustrate Variations in Structure in the Same Sheet of Rolled Sheet-Steel after Annealing

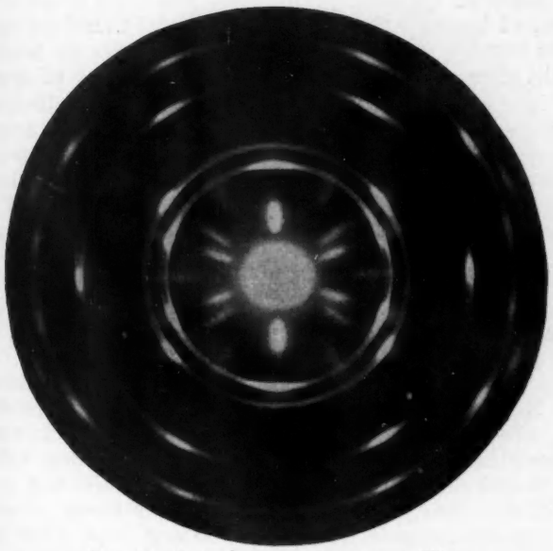


FIG. 11—STRUCTURE OF ALUMINUM WIRE
The View Is a Fiber Diagram of a Cold-Drawn Aluminum-Wire That Was Subjected to Various Annealing Treatments and Followed by a Measurement of Tensile Strength and the Making of X-Ray Diagrams

brasses leading finally to pure zinc. While there are some discrepancies in the results, the various phases of the copper-zinc system are for the first time becoming understood and the conditions are becoming established whereby brass of a given composition and desired properties can be obtained.

X-RAY ANALYSIS OF STEEL

The facts established by X-ray analysis of steel can be summarized briefly as follows:

Austenite is a solid solution of carbon or cementite (Fe_3C) in γ-iron; it crystallizes in the face-centered cubic system

Cementite, the only definite compound formed by iron and carbon, crystallizes in the orthorhombic system.

Ferrite is body-centered cubic α-iron with the possibility of 0.3 per cent of carbon in solid solution

Martensite gives the pattern of α-iron with very broad lines, indicating either small particles or distortion. Though there is a wide difference of opinion, the majority of metallurgists consider that it is a solid solution of cementite in α-iron

High-speed and special-alloy steels such as are used widely in automotive construction give diffraction spectra with as many as 100 lines which, so far, have not been interpreted completely. In Sweden, Westgren and Phragmen are doing a notable work in synthesizing these complex spectra by a systematic study of the systems tungsten, molybdenum, and chromium with carbon. They have already identified from the spectra such compounds as Cr_4C (cubic), Cr_2C_3 (hexagonal), Cr_3C_2 (orthorhombic), WC (hexagonal), and the like,[5] as well as the solid-solution limits. It can be predicted safely that within a year a far greater knowledge of these alloy steels will be gained from systematic X-ray investigation and that new metallurgical advances can be made in the automotive field upon the basis of these scientific facts.

EFFECTS OF FABRICATION OF METALS

Regarding the general evidences of mechanical and of heat-treatments, of even greater commercial importance than the determination of constitution of metals and alloys by X-rays is the detection of the effects of any kind of fabricating process upon metals in terms of structure and of practical behavior. The photographs presented herewith illustrate in general the possibilities of the type of examination.

The two views at the left of Fig. 10 show the diffraction patterns obtained with ordinary low-carbon sheet-steel after hot and after cold rolling. Both show the characteristic fiber evidences, which indicate that these metals must have directional properties. The cold working produces more of the fibering than does the hot rolling. Both processes evidence radial streaks that are indicative of distortion strain. The lack of symmetry in the

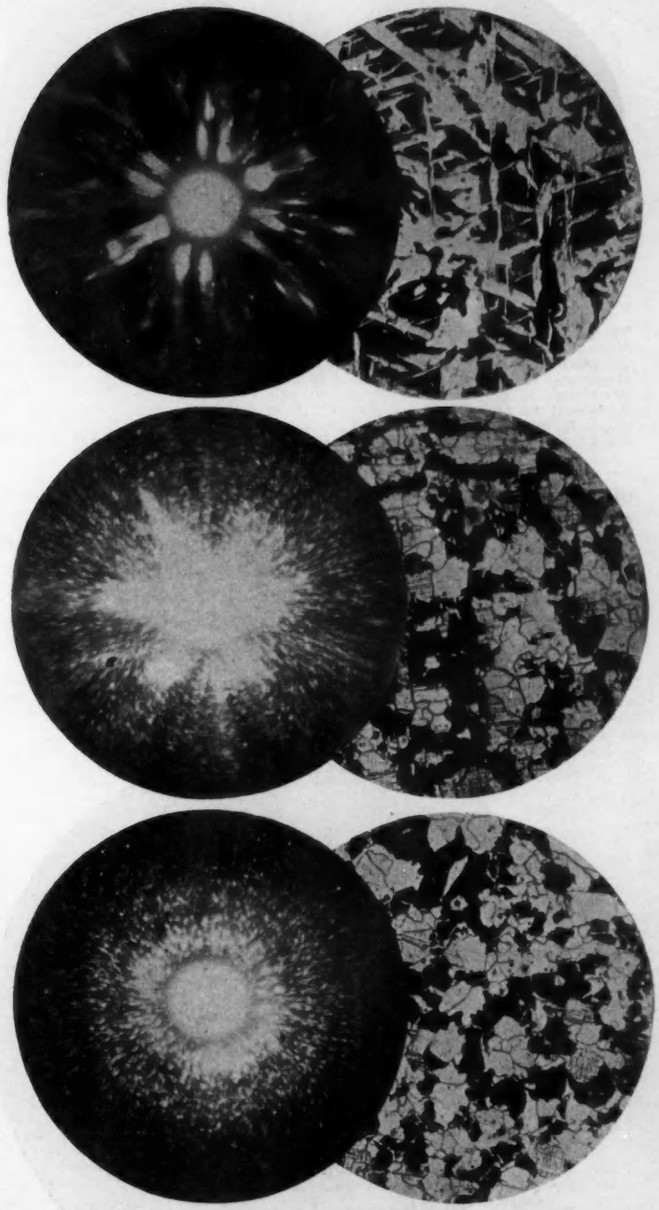


FIG. 12—PRACTICAL IMPORTANCE OF THE PINHOLE METHOD FOR X-RAY DIAGRAMS
The Top Diagram and Photomicrograph Are Those of Cast Steel as Cast; the Middle View Is for Cast Steel after 5 Hr. of Annealing Treatment; and the Bottom View Is for Cast Steel after Four 5-Hr. Anneals. The Coarse Non-Uniform Grain-Mass of Steel as Ordinarily Cast, Shown in the Top View, Is by No Means Obliterated in the Standard Annealing-Processes, as the Middle View Indicates. The Removal of Internal Stresses Is Not Impossible under Proper Annealing-Conditions. The Ideal Structure of Small Equi-Axed Crystals with Neither Directed Orientation nor Internal Strain Is Shown in the Bottom View, for the Same Casting

[5] See *Kungl. Svenska Vetenskapsa Handlinger* No. 5, 1926; see also *Zeitschrift für Anorganische Allgemeine Chemie*, vol. 156, p. 27.

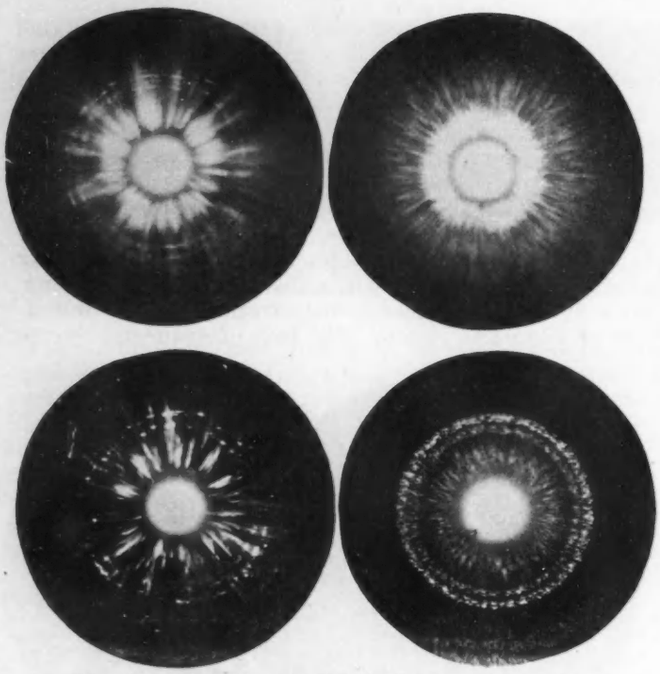


FIG. 13—X-RAY DETERMINATION OF WELD STRUCTURE

The X-Ray Structure of a Lap Weld Obtained by the Ordinary Arc-Method in Air Is Shown by the Two Upper Views. The Structure as Obtained by the General Electric Co. Method of Welding in Hydrogen Is Shown in the Two Lower Views. For Each Pair, the Structure in the Weld Is Shown at the Left, and That of the Metal Adjacent to the Weld Is Shown at the Right. The Variations in Particle Size and Strains in the Various Zones between the Weld Metal and the Original Bar-Metal Were Clearly Disclosed by the X-Ray Photographs

diagrams results from the fact that the direction of last pass through the rolls determines the structure and the diagrams, which correspond to a rolling direction from bottom to top. Subsequent heat-treatment of course relieves both the strain and the directional properties. The X-ray method is extremely sensitive to this process, as is illustrated by the two patterns at the right in Fig. 10, taken at different positions of the *same* sheet. The effect of temperature on a worked metal therefore manifests itself especially in a reversible change in position of the grains and a new forming and enlarging of grains.

Fig. 11 is the beautiful fiber-diagram of a cold-drawn aluminum-wire. This was subjected to various annealing treatments and followed by a measurement of tensile strength and the making of X-ray diagrams, as follows: At 150 deg. cent. (302 deg. fahr.) for ½ hr., 18.7 kg. per sq. mm. (26,602 lb. per sq. in.), the original specimen being 24.4 kg. per sq. mm. (34,711 lb. per sq. in.); at 200 deg. cent. (392 deg. fahr.) for ½ hr., 14.3 kg. per sq. mm. (20,343 lb. per sq. in.); at 250 deg. cent. (482 deg. fahr.) for ½ hr., 11.0 kg. per sq. mm. (15,648 lb. per sq. in.); and essentially the same for 300 deg. cent. (572 deg. fahr.) and for 550 deg. cent. (1022 deg. fahr.). The X-ray diagrams show a gradual increase in particle size, with fine dots appearing on a continuous background of the diffraction rings at 250 deg. cent. (482 deg. fahr.) and at 300 deg. cent. (572 deg. fahr.). At 550 deg. cent. (1022 deg. fahr.) large spots appear, far fewer in number but still lying in rings. At 150 deg. cent. (302 deg. fahr.) fiber interference maxima broaden, indicating a departure of the oriented particles from perfect alignment; but even after annealing at 550 deg. cent. (1022 deg. fahr.), strong evidences of the fiber structure remain.

CAST STEEL

Apparently, the first organized study of cast metals was made by Clark and Aborn on steel castings,[6] but is as yet unpublished. Although it is commonly thought that cast metals generally exhibit a random orientation of grains, an examination of Fig. 12 will show the great practical importance of the pinhole method in this field. The coarse non-uniform grain-mass of steel as ordinarily cast, shown at the top of Fig. 12, is by no means obliterated in the standard annealing-processes, as the middle view of Fig. 12 shows. The removal of internal stresses is not impossible under proper annealing-conditions. The bottom view of Fig. 12, for the same casting, shows the ideal structure of small equiaxed crystals with neither directed orientation or in-

[6] See *Industrial and Engineering Chemistry*, vol. 17, p. 1142; see also *Tech Engineering News*, April, 1926, p. 54; see also thesis for the Massachusetts Institute of Technology, by A. G. Aylies and H. C. Gilgan.

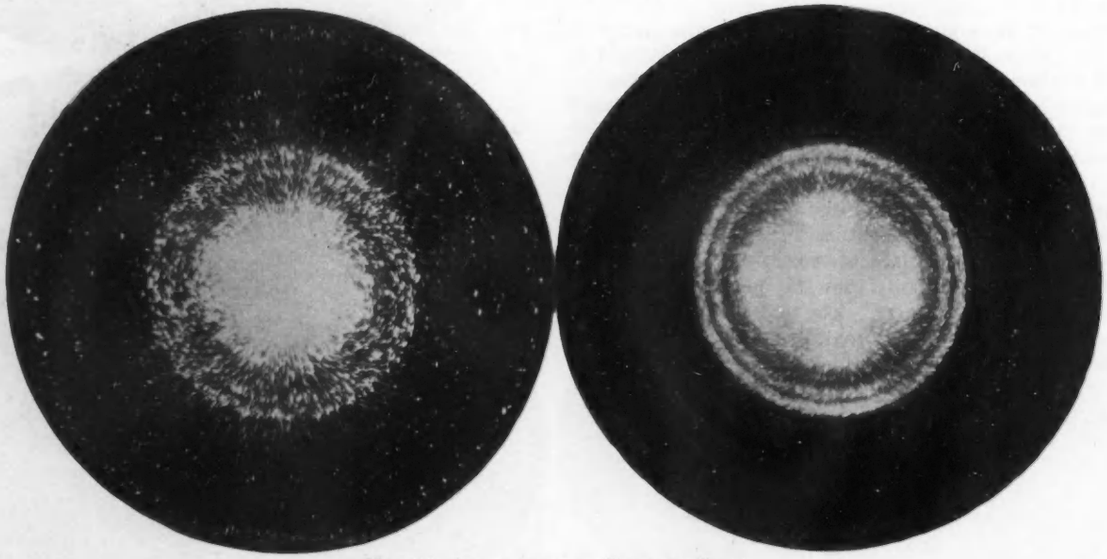


FIG. 14—STRUCTURES OF FORMING STEEL

One of the Great Metallurgical Problems at Present Is a Satisfactory Test or Method of Prediction of the Behavior of Steels in Forming. Photomicrograph and Physical Tests May Often Be Identical for Two Sheets, Yet One Will Crack in Forming While the Other Easily Withstands the Strain. X-Ray Diffraction-Patterns of Such a Pair of Sheets Are Shown, the Satisfactory Sheet Being Represented at the Left and the Unsatisfactory Sheet at the Right

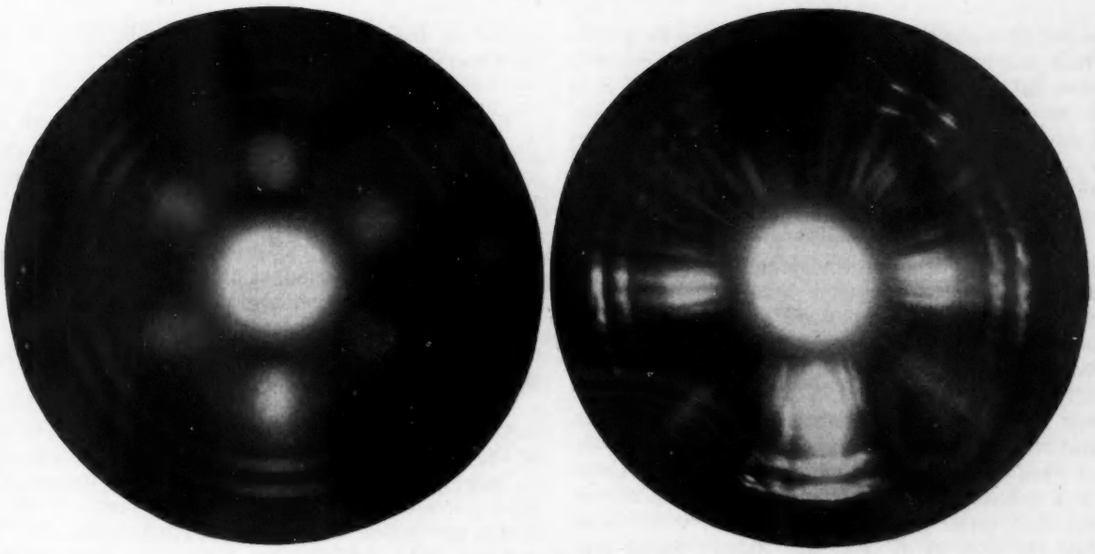


FIG. 15—STRUCTURES OF SHEET STEEL AFTER FORMING
Satisfactory Structure Is Shown at the Left and Unsatisfactory Structure at the Right. A Very Sensitive Method Is Required because the Photomicrographs May Appear To Be Identical

tensity maxima nor internal strain or radial asterism striation.

A casting of irregular form, radiographically perfect in freedom from holes, cracks and inclusions, was examined by the Laue pinhole method to ascertain the uniformity of structure and the distribution of strain. In the same casting, depending upon the thickness of the cross-section and the zone relative to the mold or core wall, the diagrams varied as widely as those at the top and bottom of Fig. 12. Upon the basis of the X-ray photographs alone, it was possible to plot regions of equal strain or "isostrainal" lines and to predict how and where the casting would fail and crack. Upon the basis of these facts it was thus possible to introduce modifications in the casting technique, particularly in the annealing, following each change with the X-ray diagrams and thus arriving at castings that were far superior in uniformity of structure. In the field of casting, therefore, this represents a great advance in research beyond the point of the radiographed casting. The information pertains to the fine structure and to the phenomena not otherwise observable.

In agreement with the facts presented in the preceding section of this paper, the last traces of asterism or strain in steel castings are remarkably persistent. In a comprehensive study of the effects of annealing upon fine structure it was found that, for blocks only ½ in. thick, heating for 20 hr. at 900 deg. cent. (1652 deg. fahr.) was necessary for removal of the last traces of inhomogeneity, although improvement was observed successively at intermediate times. Changes in the particle size and strain during annealing and the effects of the method of cooling, either slowly in the furnace or by quenching in air, water and oil, were all easily determined by the X-ray diagrams.

WELDS

The determination of the structure of welds from the X-ray diffraction-diagram has been very illuminating, particularly when these results are combined with photomicrographs and tensile-strength tests.[7] The specimens were various butt and lap welds produced by the arc method in air, shown in the upper pair of Fig. 13, and

[7] See thesis for the Massachusetts Institute of Technology, by Lieut. F. H. Whitaker.

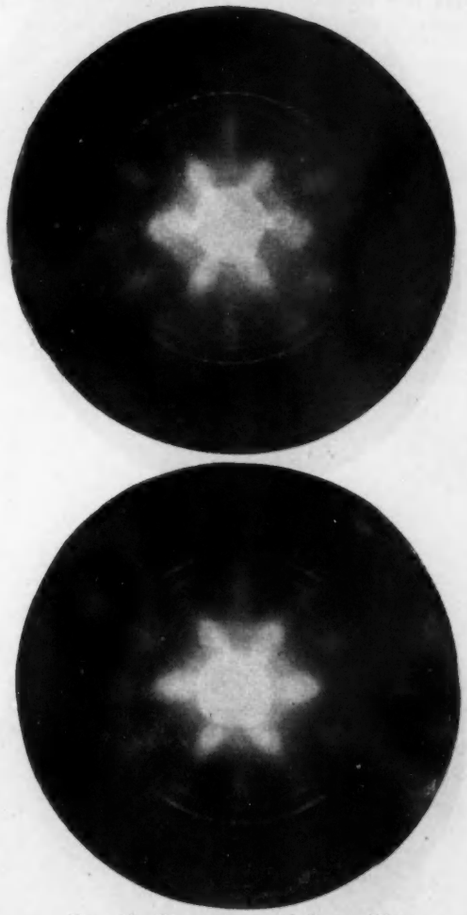


FIG. 16—STRUCTURES OF STEEL WIRE
Determination of the Cause of the Cutting of Dies during the Drawing of Steel Wire Has Previously Proved Difficult. The Structures of Partly Finished Low-Carbon-Steel Wire after an Intermediate Anneal Are Depicted. The Wire Represented in the Upper View Gave a Satisfactory Subsequent Drawing and That in the Lower View an Unsatisfactory, or Over-Size, Drawing. The Evidence Is Convincing That the Unsatisfactory Wire Was Improperly Annealed and Was Too Hard, Since the Fibering Is Still Strong and the Grain Size Is Small as Compared with the Properly Annealed Sample Having the Structure Shown in the Upper View

by the General Electric Co.'s method of welding in hydrogen, shown in the lower pair. The variations in particle size and strains in the various zones between the weld metal and the original bar-metal, were clearly disclosed by the X-ray photographs. The maximum strain as judged by asterism is observed in the top of the weld metal, where the last metal has been added and the cooling has been most rapid; while the smallest particle-size is in the refined zone of the original metal adjoining the weld. The hydrogen-atmosphere welds are distinguished from the ordinary type by larger grain-size but a far more uniform grain-size throughout all the zones, even in the refined zone, and a much greater freedom from strain, as if the composite structure were annealed. The oxide impurities at grain boundaries in the ordinary welds are clearly absent in the hydrogen welds so that there is no interference with grain growth. In spite of large grains in random orientation, these welds are fairly ductile, illustrating an important metallurgical fact that large grains do not necessarily mean brittleness of the specimen. Further improvements undoubtedly will result in a still more satisfactory weld, and X-rays may play a primary role in such improvements that will lead to new standards and new specifications in the numerous instances in which welds are necessary.

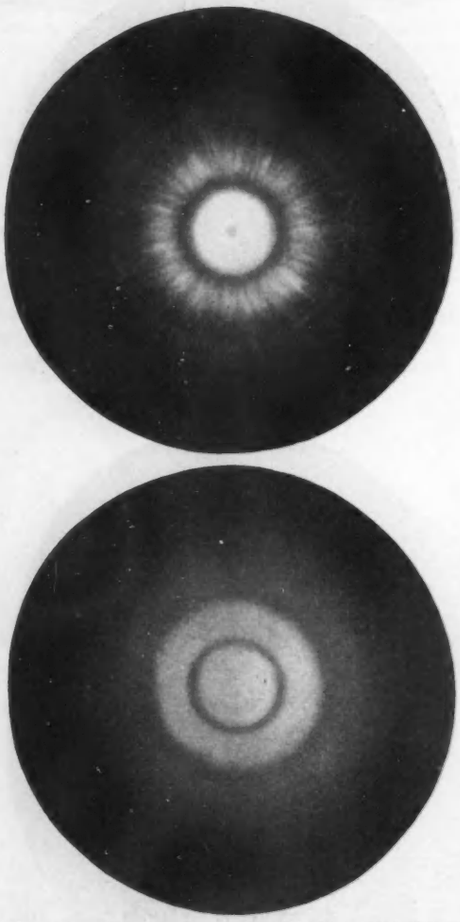


FIG. 17—STRUCTURE OF CASE-CARBURIZED STEEL
The Diffraction Diagram for Low-Carbon Steel Case-Carburized and Cooled in the Carburizing Pot Is Shown in the Upper View. Due to the Large Crystals Which Have Been Strained as a Result of the Differential Volume-Changes During Cooling, Asterism Appears. In the Lower View, the Material Represented in the Upper View Has Been Hardened by an Oil Quench. The Broad Diffuse Rings Indicate Small Crystal-Size and Absence of Preferred Orientation Which Was Present in the Original Untreated Low-Carbon Steel

FORMING STEEL

The prime requisite of a good forming-steel such as is used in stamping operations like those for automobile radiators is very evidently an absence of any directional properties; hence, the grains should be equi-axed and well knit together without strain or fibering. One of the great metallurgical problems at present is a satisfactory test or method of prediction of the behavior of steels in forming; photomicrographs and physical tests may often be identical for two sheets, and yet one will crack in forming while the other easily withstands the strain.

Fig. 14 is a reproduction of the X-ray diffraction-patterns of such a pair of sheets, the good sheet being shown at the left and the bad one at the right. The difference is unmistakable; the sheet that fails invariably shows strong evidence of a residual preferred orientation and strain and often shows an unsymmetrical and distorted pattern. The satisfactory sample is distinguished by a pattern approaching the continuous Debye-Scherrer rings of a random aggregate which thus has the same properties in all directions.

The two views of Fig. 15 show the structures of sheet steel after forming, whether satisfactory or unsatisfactory. A very sensitive method is required because the photomicrographs may appear identical. The development of a technique of manufacture and particularly of annealing practice which will reduce rolling strain to the minimum and assure uniformly good forming-steel might well be made upon the basis of the X-ray method.

STEEL WIRE

A difficult metallurgical problem has been to determine the cause of the cutting of dies during the drawing of steel wire. One explanation has been that the wire is too hard in some parts; another has been that there are soft spots. Fig. 16 shows the structures of partly finished low-carbon-steel wire after an intermediate anneal; the wire represented in the upper view gave a satisfactory subsequent drawing and that in the lower view an unsatisfactory, or over-size, drawing. The evidence is convincing that the unsatisfactory wire was improperly annealed and was too hard, since the fibering is still strong and the grain size is small as compared with the properly annealed sample having the structure shown in the upper view.

CASE-HARDENED STEEL AND STEEL FOR ELECTRICAL USE

In the upper view of Fig. 17 is shown the diffraction diagram for low-carbon steel case-carburized and cooled in the carburizing pot. Due to the large crystals that have been strained as a result of the differential volume-changes during cooling, asterism appears. In the lower view of Fig. 17, the material represented in the upper view has been hardened by an oil quench. The broad diffuse rings indicate small crystal-size and absence of preferred orientation that was present in the original untreated low-carbon steel. By X-ray studies it has been possible to determine all the structural conditions, from raw material to finished product, leading to maximum wear. Studies in hardness and wear will be published in detail.

In reference to steel suitable for electrical construction, one of the most eloquent examples of the value of X-ray diffraction-research in metallurgy is in the field of the steels used as cores of transformers and the like where the magnetic properties are the chief concern.

These metals usually contain 3 or 4 per cent of silicon, together with carbon and the usual impurities. It has long been known that large grain-size is an important factor, but specifications usually are based upon the magnetic hysteresis-loss in watts per pound. Fig. 18 shows the diffraction patterns of a series of silicon-steel samples, differing essentially in the annealing only. The upper left view shows the original structure of the rolled steel before annealing; the upper right, a partial or unsatisfactory anneal showing a high hysteresis-loss of 0.8636 watts per lb.; the lower left, a controlled anneal showing a low hysteresis-loss of 0.5535 watts per lb.; and the lower right, an anneal and subsequent straining such as is introduced in a punching operation.

It is at once apparent that, as the hysteresis losses decrease, the diffraction spots become larger and fewer in number, culminating for minimum loss and best magnetic-properties in the Laue diagram of a single-crystal grain extending through the sheet, as indicated in the lower left view. The faulty annealing of the poorest specimen, that in the upper right view, is further shown by the four clustered intensity maxima symmetrically placed around the direct-beam spot; these are residual evidence of the fibering originally produced by the rolling of the sheets before heat-treatment. The X-ray pattern alone may serve, therefore, as evidence of the magnetic properties of the silicon steel, for the essential attribute is the minimum number of unstrained single grains; and this number is proportional roughly to the number of spots on the X-ray pattern.

From a large number of experiments on a 4-per cent silicon-steel,[8] an empirical equation connecting the number of diffraction spots with the hysteresis loss has been derived. It is $W = 112\sqrt{(P)} + 400$, where P is the number of spots per square inch taken at the same place on the diagrams, and W is the hysteresis loss in ergs per cubic centimeter, at 60 cycles and 10,000 gausses induction. Upon unduly thickening grain boundaries by excessively long annealing or by successive straining, however, the relation can be invalidated, showing that,

[8] See thesis for the Massachusetts Institute of Technology, by L. V. Peaks and F. P. Broughton.

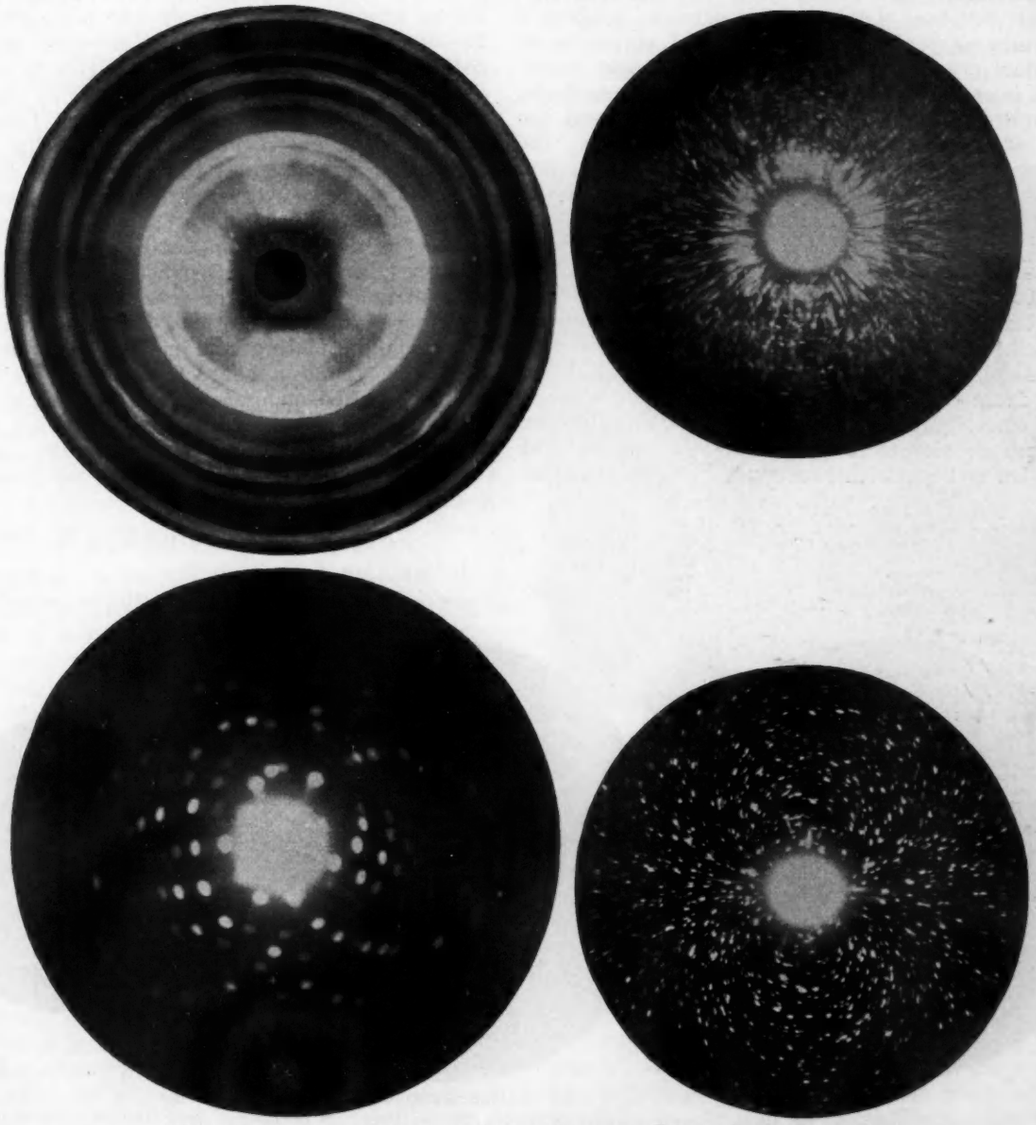


FIG. 18—DIFFRACTION PATTERNS OF A SERIES OF SILICON-STEEL SAMPLES

The Samples Represent Steel Suitable for Electrical Construction and Differ Essentially in the Annealing Only. The Upper Left View Shows the Original Structure of the Rolled Steel before Annealing; the Upper Right, a Partial or Unsatisfactory Anneal Showing a High Hysteresis-Loss; the Lower Left, a Controlled Anneal Showing a Low Hysteresis-Loss; and the Lower Right, an Anneal and Subsequent Straining Such as Is Introduced in a Punching Operation.

besides grain-size, the orientation of even large grains and the condition of the grain boundaries are factors in performance. It has been found possible to improve any sample by annealing at 1675 deg. fahr. for 1 hr., but higher temperatures are detrimental. Both X-ray and magnetic tests on several steels used in radio transformers have proved some to be excellent and some very poor. X-ray research should assure a satisfactory and uniform product. The extensive researches on steels for electrical use already completed will be made the subject of a comprehensive paper.

Electrodeposited Metals

X-ray studies of electrodeposited metals have been made by Kirchner[9]; Glocker and Kaupp[10]; Clark, Brugmann and Heath[11], and Bozorth[12]; Clark and Frölich[13] for nickel; and by Frölich, Clark and Aborn[14] for lead. There is general agreement among the investigators that the metals are all crystalline, even though very hard deposits may have sub-microscopic size; under certain conditions, particularly low-current density—but high-current density for lead deposits—the deposits present a fiber structure or preferred orientation of planes in all the individual crystals, with respect to the fiber direction, which is perpendicular to the surface of the cathode, or parallel to the streamlines of the current; and the conditions of deposition, such as current density; the constitution, concentration, P_h value, temperature, and agitation of the electrolyte; the thickness of the deposit; hydride formation; the nature of the base metal; and the like, affects the crystal size and the tendency to fibrous structure, depending upon the metal.

Frölich, Clark and Aborn examined lead deposits from acetate, nitrate, perchlorate, fluoborate, and fluosilicate electrolytes in the presence and in the absence of free acid and of gelatin as an addition agent. Comparisons were made from the viewpoints of grain size, preferred orientation and strain. From a practical viewpoint the deposit from perchlorate in the presence of excess acid and of gelatin is best, with maximum cathodic-polarization, minimum grain-size, absence of dendrites, and preferred orientation. The left and central views of Fig. 19 show the structure obtained from this electrolyte both without and with a trace of gelatin, which greatly decreases particle-size. The tendency of electrodeposited lead is to form trees or dendrites. The Laue photograph of a dendrite shown at the right of Fig. 19 depicts a perfect 12-pointed star; the asterism radii are similar to those obtained with a stressed metal-aggregate wire. Many other interesting properties of electrodeposited metals, as deduced from their structural patterns, are discussed in the original papers.

[9] See *Annalen Physik*, vol. 69, p. 59.
[10] See *Zeitschrift für Physik*, vol. 24, p. 121.
[11] See *Industrial and Engineering Chemistry*, vol. 17, p. 1142.
[12] See *Physical Review*, vol. 26, p. 390.
[13] See *Zeitschrift für Elektrochemie*, vol. 31, p. 655.
[14] See American Electrochemical Society Preprint; see also *Zeitschrift für Elektrochemie*, vol. 32, p. 295.

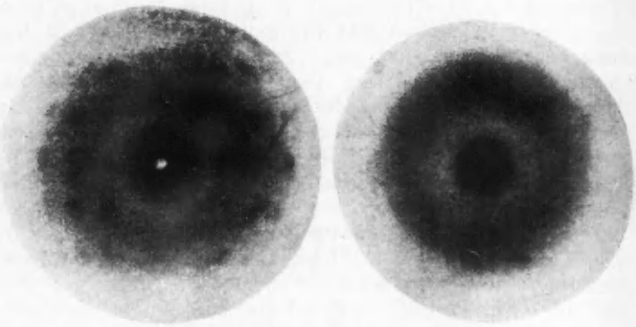


Fig. 20—X-Ray Structure of Rubber

Raw or Vulcanized Rubber Normally Produces the X-Ray Diagram of an Amorphous Substance, a Single Broad and Diffuse Ring, as Shown at the Left. Upon Stretching Raw Rubber More Than 80 Per Cent, a Fiber Diagram Appears Which Indicates the Presence of Diffracting Material That Acts Entirely Like Ordinary Crystals. The Intensity of These Spots Increases Linearly with the Percentage of Elongation, the Intensity of the Broad "Amorphous" Ring Decreasing Linearly at the Same Time as Shown at the Right

Great opportunities for research still lie open in this field, particularly since there is now such great interest in chromium plating and since Westgren and Phragmen have found a characteristic new lattice-type for electrodeposited manganese, and Bradley and Ollard for chromium. Further careful researches are required also to settle the controversy concerning the structural factors which control the hardness of electrodeposited metals.

Non-Metallic Automotive Materials

In addition to the application of X-rays to the innumerable phases of the constitution, structure and be-

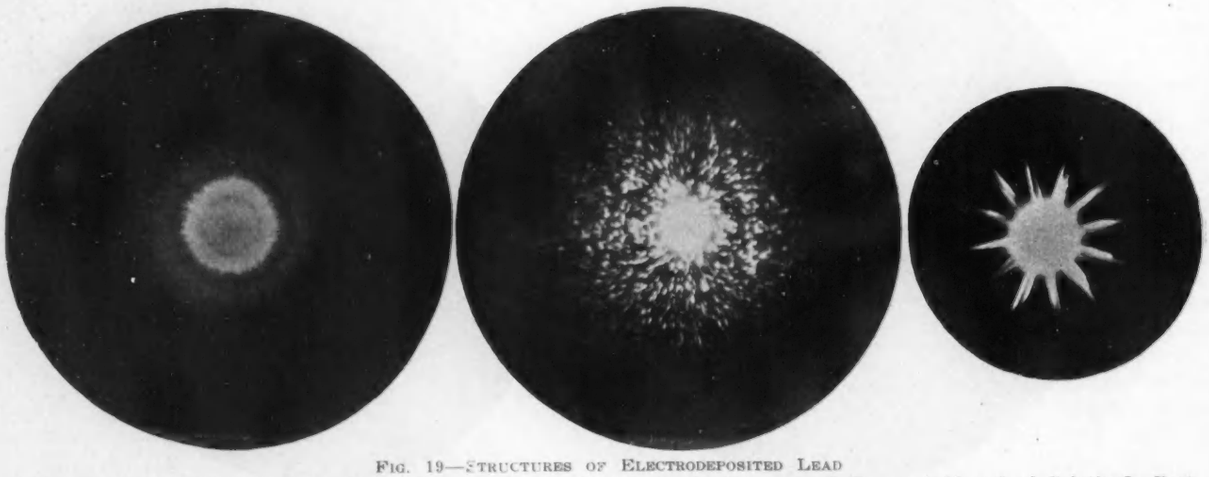


Fig. 19—Structures of Electrodeposited Lead

From a Practical Viewpoint, the Lead Deposit from Perchlorate in the Presence of Excess Acid and of Gelatin Is Best, with Maximum Cathodic-Polarization, Minimum Grain-Size, Absence of Dentrites, and Preferred Orientation. The Left and Central Views Show the Structure Obtained from This Electrolyte Both Without and With Trace of Gelatin, Which Greatly Decreases Particle Size. The Left View Is That of a Dentrite and the Central View Represents the Deposit from Fluoborate Electrolyte. The Tendency of Electrodeposited Lead Is To Form Trees of Dentrites. The Laue Photograph of a Dentrite Shown at the Right, Being That of the Lead Deposit from Fluoborate Electrolyte with 0.5 Grams of Gelatin per Liter of Solution, Depicts a Perfect 12-Pointed Star, the Asterism Radii Being Similar to Those Obtained with a Stressed Metal-Aggregate Wire

havior of metals and alloys, there are a number of other materials with which the automotive industry is concerned and which can be subjected to X-ray scrutiny with equally valuable results.

The extraordinarily striking results of the study of rubber, balata, gutta percha, and the like by X-rays are the subject of a recent somewhat extended paper,[15] but a brief recapitulation will suffice here.

(1) Raw or vulcanized rubber normally produces the X-ray diagram of an amorphous substance, a single broad and diffuse ring as at the left of Fig. 20

(2) Upon stretching raw rubber more than 80 per cent a fiber diagram appears which indicates the presence of diffracting material that acts entirely like ordinary crystals. The intensity of these spots increases linearly with the percentage of elongation, the intensity of the broad "amorphous" ring decreasing linearly at the same time as shown in the right view of Fig. 20. The width of the spots remains constant, showing that new individuals are being produced instead of a growth of nuclei already present

(3) This phenomenon is reversible, since the diffraction pattern disappears when the tension is released; an increase in temperature weakens the diagram so that, at 60 deg. cent. (140 deg. fahr.), no interferences appear

(4) The fiber diagram easily can be interpreted to prove a rhombic-crystal system of the dimensions 7.68 x 8.00 x 8.60 Angström units, containing four C_5H_8 molecules, or possibly eight such molecules. At least 2000 molecules of C_5H_8 comprise the rubber colloidal particle or micelle

(5) All the data strongly support the theory that preformed swollen aggregates exist in rubber. Upon stretching, the swelling agent, low-polymer-rubber hydrocarbon, is squeezed out of the high-polymer hydrocarbon, which is then aligned as in a fiber and diffraction can occur

(6) Milling, heating, fractionating, freezing, vulcanizing, compounding, and aging of rubber all produce definite effects that can be ascertained from X-ray diffraction-data. Comprehensive experiments designed to study the effect of all these practical operations are now under way

The groundwork has now been laid for practical X-ray studies of carbon blacks. Our researches have demonstrated that it is possible to proceed continuously from amorphous active charcoal through a paracrystalline state in which the chemical properties are like those of graphite, but crystal planes are still too few and distorted to produce measurable X-ray crystal-interferences; then to colloidal graphite with very broad spectrum lines and finally to crystalline graphite. Accurate determination of particle sizes is made with the aid of a precision microphotometer. From this study, scientific preparation of blacks for rubber fillers and for various other specific purposes should follow. The measurement of particle size as a function of behavior is part of a comprehensive program in which the particle size, activity and specificity of catalysts are being correlated.[16]

Probably the most perfect natural fibers are those of asbestos. In Fig. 21 is reproduced the diffraction pattern for chrysotile; the hyperbolas upon which the intensity maxima lie are an indication of the perfection of fibering. In the course of experiments on the best asbestos for a catalyst base it was discovered that asbestos from various sources could be differentiated by X-ray diagrams, without recourse to involved chemical tests or actual trial. Once a specimen has been found which stands up under the conditions of temperature and chemical environment for catalyst bases, its X-ray diagram identifies it. Purchase of further supplies can be made upon the basis of a single X-ray diffraction-photograph of the new material. The correlation between behavior and ultimate structure is complete. The process is now extended to asbestos for brake-linings, where strength, resistance to heat and abrasion are essential. The X-ray method here constitutes a very extraordinary and simple control test. Complete data and diagrams of the various types of asbestos are available.

While textile fibers do not come into prominence in the automotive industry, still it is interesting from the viewpoint of upholstery to note that they can be studied very completely with X-rays. All natural cellulose fibers, such as cotton, sisal, ramie, jute, hemp, and flax; all rayon fibers, except possibly diacetate of cellulose; and the protein fibers, silk and wool, yield typical crystal fiber diffraction-patterns such as are shown in the left view of Fig. 22. For cellulose, these prove the composition $(C_6H_{10}O_5)_4$ as the ultimate unit. The diagram

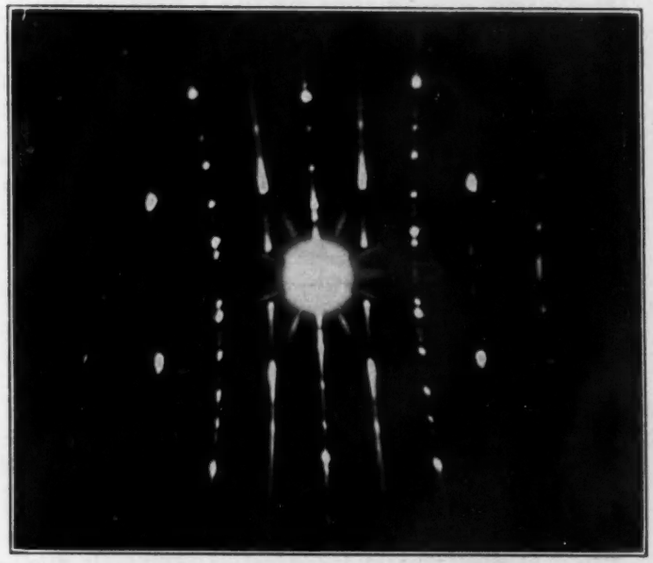


FIG. 21—TYPICAL X-RAY DIAGRAM OF ASBESTOS
The Diffraction Pattern Is for Chrysotile. The Hyperbolas upon Which the Intensity Maxima Lie Are an Indication of the Perfection of Fibering

changes under mercerization of the material, indicating a chemical change. Swelling, aging, dyeing, laundering, and the like all produce in some degree a typical change. The textiles have been fully considered in a recent paper.[17]

No directly practical studies of the structures of spark-plug porcelain or other dielectrics have as yet been made, but the field is promising. X-ray analyses of various ceramics such as sillimanite, mullite, disthene, andalusite, and the like have distinguished between them clearly. The great similarity in the spectra of the first two indicates that the crystalline phase of mullite may be $Al_2O_3.SiO_2$ instead of $3Al_2O_3.2SiO_2$. An effective study of particle size is of course possible in the manufacture of spark-plug porcelain.

Regarding lubricants, one of the greatest recent advances in X-ray crystallometry has been the study of

[15] See *Industrial and Engineering Chemistry*, vol. 18, p. 1131.

[16] See X-Ray and Colloids, by G. L. Clark, being the Fourth Colloid Symposium Monograph.

[17] See *American Dyestuff Reporter*, December, 1926; see also thesis for the Massachusetts Institute of Technology, by B. R. Freudenthal and M. P. Kulp.

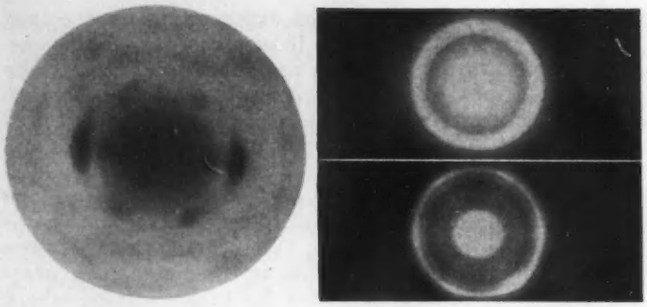


FIG. 22—TYPICAL X-RAY DIAGRAMS OF A TEXTILE FIBER AND OF A LUBRICANT
All Natural Cellulose Fibers Yield Typical Crystal Fiber Diffraction-Patterns, the Pattern at the Left Being That for Ramie. The Structures of a Solid Lubricant, a Grease, Are Shown in the Two Views at the Right, the Upper View Being That for Grease in Bulk, or Unworked, and the Lower View Being That for Worked Grease, as in a Bearing

the structures of long-chain organic-compounds such as paraffin hydrocarbons, acids, soaps, alcohols, ketones, esters, and the like. Under proper condition of sample preparation crystal spectra are obtained, with one spacing corresponding to the length of the molecule; the introduction of successive carbon atoms into the chain produces generally a constant increment in the length. The hydrocarbons therefore are like a stack of carpets, the molecules being the pile of the carpets perpendicular to equidistant parallel layers; the fatty acids are like the stack with the carpets in pairs with the pile in contact.

There are two important phases to the foregoing problem: one is the study of constitution of a given sample, since the molecular weight can be deduced directly from the observed long spacing; the other has to do with the very particular conditions under which it is possible to prepare the compounds so that these long-spacing spectrum-lines, indicative of molecular orientation, will appear. In other words, with the same compound it is possible to obtain or not to obtain the diffraction spectrum, depending entirely upon external conditions that will permit or prevent the parallel orientation of the long molecules. Experiments have proved that the following conditions are favorable for orientation and, thus far, for the production of the spectra: (*a*) a dry surface, (*b*) a neutral or slightly alkaline surface, (*c*) a sufficiently thin layer of the substance, and (*d*) a finite time before solidification takes place to allow the molecules to align themselves.

The foregoing type of investigation is directly applicable to lubrication, not only to the solid and to the semi-solid greases but also to liquid oils. Bulk greases, such as triglycerides and the like, appear entirely amorphous in bulk and, as such, produce essentially amorphous X-ray diagrams. If, however, a thin layer is worked, by pressing with a spatula or between two metal surfaces as in a bearing, a film is produced which gives beautifully intense orientation spectra, indicative of the stratification of the material. If there is an active group in the molecules, such as carboxyl in acids and glyceride radical, these are orientated toward the metallic surface leaving an outer layer essentially of a methane group, CH_3, over which gliding is accomplished easily. The more perfect the orientation is, the more perfect is the actual lubrication. Some of these films are of remarkable stability. The strength of a soap-bubble film lies in the perfect orientation of a double layer of molecules; a layer of oleic acid on metal clings so tenaciously that it cannot be removed save by strong abrasion. We are now obtaining evidence of orientation in the liquid oils although, in this field, on account of thermal agitation, it is somewhat more difficult to obtain intense spectra.

Here, then, is a great new application of X-ray spectra in the analysis of lubricants and in the determination of the conditions under which the best spectra are obtained, and therefore under which lubrication is most efficient. Our own experiments have indicated that this necessary molecular orientation occurs through less than 1/20 mm. (0.001968 in.) and that the really effective lubricating-film is one that is very few molecules thick. The two views at the right of Fig. 22 show a grease unworked and worked. The circles that appear do not correspond to the long dimension but to the cross-section of the molecules. The fibering produced by stroking is clearly evident.

PAINTS, PIGMENTS, VARNISHES, WAXES AND SHELLAC

All these materials, ordinarily never considered in the light of X-ray examination, are yielding extraordinarily interesting results. The polymerization and oxidation of linseed oil, the chemical identity and particle size of pigments, the changes of paint while drying, the structure and aging of waxes, the polymerization of shellac, the differences between various resin-fractions, and many other phenomena in some distinctly non-crystalline materials, are being detected and followed. With most of these amorphous materials it is possible to obtain three broad diffraction-rings, the spacings of which are very characteristic and sensitive to chemical change. The appearance of truly crystalline matter is at once registered. The fact remains that "crystal" means something far more from the X-ray diffraction-viewpoint than a solid body bounded by geometrical planes. Even the appearance of a single broad ring, instead of general blackening, is indication of some kind of a fragmentary or sub-crystalline state, even in liquids. If there is any kind of arrangement of atoms and molecules, X-rays detect it. Upon this basis, therefore, all liquid or solid materials are potential specimens for X-ray examination for ultimate structure and for the fundamental differences between satisfactory and unsatisfactory raw or manufactured products.

BRAKE CUP LEATHERS DO NOT LEAK

IN the paper on Brakes for Automotive Use which was presented at the March, 1926, meeting of the Southern California Section by John Wiggers and which was printed in the January, 1927, issue of THE JOURNAL, the statement was made on p. 144 in the paragraph in the second column describing the Christensen type of air brake that "its disadvantage may be that it has cup leathers which are liable to leak." This statement is not correct at present according to Fred Neale, chief engineer of the Christensen Air Brake Co., who has written the office as follows:

> Nine months ago, where the brake cylinder was subject to considerable heat, this statement regarding the leakage of brake cylinder cup leathers would have been true. . . . Recent development has resulted in a metal cap which is impervious to oil and heat within the range associated with satisfactory brake operation, is leak proof and will have a length of life comparable to the brake cylinder in which it works.

JANUARY COUNCIL MEETINGS

A SESSION of the Council was held at New York City on Jan. 13. Those attending were President Litle; First Vice-President Hunt; Past-President Horning; Treasurer Whittelsey; Councilors Chandler and Winchester; E. T. Jones, W. G. Wall and Ernest Wooler, nominees for Councilors for next year; and A. J. Scaife, chairman, and H. M. Crane and C. M. Manly, members of the Constitution Committee.

One hundred and eight applications for individual membership which had been acted on by letter-ballot of the Council were reported and in addition 52 applications were submitted and acted on. The resignations of 56 members were accepted. Twenty-one reinstatements to membership were made; also 13 transfers in grade of membership. Five members were dropped for non-payment of dues payable Sept. 30, 1925.

STANDARDS COMMITTEE MATTERS

The following subjects were assigned to Divisions of the Standards Committee, as indicated:

Exhaust-Pipes and Mufflers—Engine Division
Dome-Light Lamp Sockets—Lighting Division
Marker-Lights—Motorcoach Division
Reports on Small Rivets and Tinners', Coopers' and Belt Rivets submitted by Sectional Committee on Bolt, Nut and Rivet Proportions—Parts and Fittings Division
Hub Bolts—Screw-Threads Division
Reports on Round Unslotted-Head Bolts and on Plow-Bolts—Screw-Threads Division
Clutch Driving-Drum—Transmission Division

C. W. Spicer was named an additional representative of the Society on the Subcommittee on Machine Tapers of the Sectional Committee on Small Tools and Machine-Tool Elements. A. J. Scaife and L. H. Palmer were appointed as representatives of the Society on the Committee on Motorcoaches of the American Electric Railway Association. J. H. Hunt was appointed to serve as a member of the Standardization Survey Committee that is being organized under the chairmanship of Secretary of Commerce Hoover to investigate the general subject of National and International standardization.

It was voted to appropriate a sum not to exceed $5,000 for a research project of head-lamp testing to be carried out by the automotive division of the Bureau of Standards, the technical control of this project to be fixed in the Research Committee of the Society.

In connection with the resolution passed by the Transportation and Service Meeting of the Society held in Boston last November the following were named as the representatives of the Society on the Joint Committee on Fundamentals of Automotive Freight Transportation: N. A. Finch, Jr., F. J. Scarr and J. F. Winchester. It was contemplated by the resolution passed at Boston that the other members of this committee of 11 would be named by the National Automobile Chamber of Commerce and the Railroad Motor Transport Conference.

In response to preliminary word received from the Institution of Automobile Engineers and the Society of Motor Manufacturers & Traders, London, it was decided to send delegates to the Commercial Motor Transport Exhibition to be held in London next November.

It was reported that the American Automobile Association had expressed a wish that the Society name a committee of five to advise on technical questions involved in the conduct of contests held by that body. President Litle and First Vice-President Hunt were requested to name such an advisory committee.

A financial statement as of Nov. 30, 1926, was submitted. This statement showed a net balance of assets over liabilities of $184,556.35, this being $21,270.41 more than the corresponding figure on the same day of 1925. The net revenue of the Society for the first 2 months of the current fiscal year amounted to $61,469.92. The operating expense during the same period was $51,714.72. The income for the month of November was $27,436.07, and the operating expense $26,774.22.

The last regular session of the 1926 Council was held in Detroit on Jan. 25, the following being present: First Vice-President Hunt, Second Vice-President Smith, Treasurer Whittelsey, Councilors Chandler and Winchester, and Chairman Whitten of the Standards Committee; also W. G. Wall, S. W. Sparrow, Ernest Wooler and C. B. Veal, nominees for 1927 Council.

Eighteen applications for individual membership were approved. Four members were transferred from Junior to Associate grade. The resignations of five members were accepted. Two former members were reinstated.

The action of the Standards Committee at its meeting held on the same day, after considering the current reports of its Divisions, was approved prior to submission of the reports to the Society at its Business Session and subsequent letter-ballot of voting members on adoption of S.A.E. Standards and Recommended Practices.

ORGANIZATION SESSION OF 1927 COUNCIL

The organization session of the 1927 Council was held in Detroit on Jan. 26, and was attended by President Hunt; First Vice-President Wall; Second Vice-Presidents Patitz and Jones; Councilors Chandler, Sparrow and Wooler; and Treasurer Whittelsey.

President Hunt announced the personnel of the 1927 Administrative Committees as follows:

CONSTITUTION COMMITTEE

H. M. Crane, *Chairman*
C. M. Manly — W. G. Wall

FINANCE COMMITTEE

W. L. Batt, *Chairman*
Joseph Bijur — W. M. Nones
W. E. Kemp — C. B. Whittelsey

HOUSE COMMITTEE

George J. Mead, *Chairman*
Julian Chase — Maurice Olley
R. B. Jackson — Howard L. Spohn

MEETINGS COMMITTEE

L. C. Hill, *Chairman*
George B. Allen — Paul Weeks
K. H. Condit — J. F. Winchester
Kingston Forbes — H. T. Woolson
E. T. Jones — O. W. Young
Earl A. Taylor — Paul G. Zimmermann
John Warner

MEMBERSHIP COMMITTEE

F. K. Glynn, *Chairman*
David Beecroft — G. A. Schreiber
J. A. Cervenka — Ernest Wooler

PUBLICATION COMMITTEE

E. P. Warner, *Chairman*
E. E. LaSchum — S. W. Sparrow
W. E. Lay — John Younger

SECTIONS COMMITTEE

F. F. Chandler, *Chairman* (member at large)
V. G. Apple, Dayton
George Briggs, Indiana
S. R. Dresser (member at large)
F. K. Glynn, Metropolitan
C. O. Guernsey, Pennsylvania
A. W. Herrington, Washington
P. B. Jackson, Buffalo
G. L. McCain (member at large)
E. B. Moore, Southern California
W. S. Nathan, Milwaukee
E. V. Rippingille, Detroit
E. W. Weaver, Cleveland

Glen Whitham, New England
R. E. Wilson, Chicago
E. C. Wood, Northern California

The names of the members who will serve this year as Chairman and Vice-Chairmen of the Standards Committee and of its Divisions were reported. K. L. Herrmann will be Chairman and C. M. Manly and A. J. Scaife, Vice-Chairmen of the Committee. The names of the Division Chairmen and Vice-Chairmen, as well as of those named by the Council for service this year on the various Divisions of the Standards Committee, will be listed in the March issues of the S.A.E. HANDBOOK and THE JOURNAL.

RESEARCH COMMITTEE

The personnel of the Research Committee and of its Subcommittees was named as follows:

H. C. Dickinson, *Chairman*

B. B. Bachman
O. C. Berry
W. G. Careins
F. F. Chandler
H. M. Crane
A. W. S. Herrington
E. R. Hewitt
H. L. Horning
H. A. Huebotter
J. H. Hunt
W. S. James
C. F. Kottering
W. E. Lay
B. J. Lemon
E. H. Lockwood
C. M. Manly
Thomas Midgley, Jr.
F. C. Mock
A. L. Nelson
V. P. Rumely
S. W. Sparrow
John Warner
E. P. Warner
R. E. Wilson

J. F. Winchester

FUELS SUB-COMMITTEE

W. S. James, *Chairman*

B. B. Bachman
O. C. Berry
T. A. Boyd
H. R. Cobleigh
H. M. Crane
H. C. Dickinson
C. F. Kettering
N. J. LeJeune
F. C. Mock
S. W. Sparrow
R. E. Wilson
J. F. Winchester

H. L. Horning

HEADLIGHT SUB-COMMITTEE

(Cooperating with the Illuminating Engineering Society)

H. M. Crane, *Chairman*

H. C. Dickinson
J. H. Hunt
E. S. Marks
C. A. Michel

John Warner

HIGHWAYS SUB-COMMITTEE

(Cooperating with the Rubber Association and the Bureau of Public Roads)

B. B. Bachman, *Chairman*

R. W. Brown
H. C. Dickinson
W. E. Lay
B. J. Lemon
C. M. Manly
J. F. Winchester

S. H. Woods

RIDING-QUALITIES SUB-COMMITTEE

H. C. Dickinson, *Chairman*

R. W. Brown
Benjamin Liebowitz
T. J. Litle, Jr.
E. H. Lockwood
C. M. Manly
E. C. Newcomb
E. P. Warner
John Warner

The personnel of the Operation and Maintenance and the Production Advisory Committees for 1927 will be published in the next issue of THE JOURNAL.

JOHN KELSEY

ANNOUNCEMENT is made regretfully that John Kelsey, president of the Kelsey Wheel Co., Detroit, died on Jan. 19 at his home in that city, aged 60 years. He was born at Detroit on June 20, 1866, and received his schooling in the public schools but only for a very limited period. When 11 years of age he left school and went to work for a paper company to earn money for the support of his widowed mother.

For 6 years he labored at odd jobs, succeeded in saving a little money and, when 18 years of age, he went into business with Albert V. McClure, the firm name being Kelsey, McClure & Co., which manufactured hardwood specialties. In 1902, he organized the Kelsey-Heebert Co., to manufacture ebony toilet articles. In 1906, he became interested in a spring automobile-wheel and, in 1907, with William Ducharme and others, he organized the Kelsey Wheel Co. The capitalization of this company was increased in 1915, and for some time all wheels used by the Ford Motor Co. were built by the Kelsey Company. Later, the business was expanded and different varieties of wheel were made for other car-builders.

Mr. Kelsey was more than ordinarily successful in business and was of the caliber that includes with such success a remembrance of his early struggles and of his early friends. It is said that hundreds of his former less-fortunate associates were given employment in his plant, and that many names of deserving friends and acquaintances were listed on his so-called "private pension list." He was an ardent admirer and patron of baseball. He is reported to have owned a one-third interest in the Detroit American League Baseball Team since 1900, and to have deserved most of the credit for organizing the Detroit Athletic Club. He was elected to Member grade in the Society on Feb. 10, 1912.

LION L. WOODWARD

L. L. WOODWARD, president of Fitz Gibbon & Crisp, Inc., of Trenton, N. J., and also president of the Autocar Co., Ardmore, Pa., died of pneumonia at his home in Trenton Junction, N. J., on Jan. 16, following a brief illness, aged 47 years. He was born on April 21, 1879, at Lancaster, Pa., and was graduated from Lancaster High School in 1895. His subsequent education was received at the Williamson Free School of Mechanical Trades, from which he was graduated as an electrical machinist in 1899.

His business career began in 1900 with Fitz Gibbon & Crisp, Inc., which was engaged in the building of bodies for commercial vehicles. Mr. Woodward progressed in this organization and became its president about 1916, which position he held at the time of his death. His connection with the Autocar Co. as president dates from April, 1926. He was also a member of the truck committee of the National Automobile Chamber of Commerce. Mr. Woodward was elected to Associate Member grade in the Society on May 28, 1926.

Standards Committee Meeting

THE regular January, 1927, Standards Committee Meeting was attended by 84 members and guests to consider and pass upon the reports submitted by the Aeronautic, Axle and Wheels, Electrical Equipment, Engine, Iron and Steel, Lighting, Motor-Truck, Parts and Fittings, Production, Screw-Threads, and Transmission Divisions, the reports having been printed in the January issue of THE JOURNAL. In opening the Meeting, Chairman Whitten said:

> In convening this meeting of the Standards Committee, I would like to say that the reports presented here have been prepared with considerable care on the part of the members of the various Divisions and Subdivisions, and this should be borne in mind in making criticisms and comments. It should be particularly borne in mind in making any suggestions for changes in the reports that the reports are intended to typify general practice, rather than specific individual applications. After this Committee has acted on the various reports, they will be passed on by the Council this afternoon, and at the General Business Meeting tonight for submission to final letter-ballot of the Society, following which the reports approved will be published in data sheet form in the March issue of the S. A. E. HANDBOOK.

REPORTS APPROVED AS SUBMITTED

The following reports, as presented by the Chairmen, or representatives, of the respective Divisions, were approved without changes or extensive discussion or criticism. The reference following each subject indicates the status of the report and the page of the January issue of THE JOURNAL, on which the report was printed.

AERONAUTIC DIVISION

RUBBER HOSE FOR GASOLINE
(*Cancellation of S.A.E. Standard, p.* 7)

STEEL WIRE CABLE
(*Cancellation of S.A.E. Standard, p.* 7)

REELS FOR CABLE
(*Cancellation of S.A.E. Standard, p.* 7)

ROUND, HIGH-STRENGTH STEEL WIRE
(*Cancellation of S.A.E. Standard, p.* 7)

STEEL CABLE LOOPS
(*Cancellation of S.A.E. Standard, p.* 7)

CELLULOSE ACETATE DOPE
(*Cancellation of S.A.E. Standard, p.* 7)

CELLULOSE NITRATE DOPE
(*Cancellation of S.A.E. Standard, p.* 7)

SPAR VARNISH
(*Cancellation of S.A.E. Standard, p.* 7)

AXLE AND STEEL DIVISION

BRAKE NOMENCLATURE
(*Proposed Revision of Present S. A. E. Standard,* p. 7)

ELECTRICAL EQUIPMENT DIVISION

INSTRUMENT MOUNTING
(*Proposed Revision of Present S. A. E. Standard, p.* 8)

WIRING COLOR-CODE
(*Proposed S.A.E. Recommended Practice, p.* 9)

THE DISCUSSION

S. R. DRESSER:—This scheme has been worked out very well but, since the subdivision started work, there has been somewhat of a development, or perhaps more extended adoption in use of electrical gasoline gages, and it is the opinion of some of the gage manufacturers that a color should be adopted for that particular circuit. The color suggested was green with a yellow tracer. When talking the matter over with these men, however, I pointed out that many of the cables manufactured today for electric gasoline-gage connections are two-conductor cables. It is my thought that this particular circuit should be given some thought, without holding up this report, and that the matter sould be referred to the Subdivision for recommendation to be considered at the Semi-Annual Meeting. In connection with this report, the section for passenger-cars specifies that all unprotected live wires shall have a red braid. General practice today is for circuits from the battery to the starting-switch and from the switch to the starting-motor to be made with what is termed a weatherproof braid, which is a black waxed finish. To adopt red coloring would mean a complete changeover in wiring specifications for that particular circuit.

P. J. KENT:—I think that the object of the color scheme should be to identify wires in car production and in service. The main thing that a man wants to know in identifying a wire is where it is connected and where it runs to. He is not interested in whether it is a live wire or protected or otherwise.

T. L. LEE:—Careful consideration was given to the thought that Mr. Kent has brought up, but the code became so complicated that we could not get agreement on such a code; so many criticisms were made that such a scheme seemed hopeless. We thought it would be better to start with a simpler code that might later be enlarged to answer the requirements of Mr. Kent's suggestion.

W. B. CHURCHER:—In reply to Mr. Dresser, I would say we had no intention of including the starter-cable in the color scheme, as there is no occasion to identify it specially. Its size is sufficient. We selected the fewest colors that would give us a reasonable means of tracing lines. It is true, in some cases, that if wires go through one conduit, they may all be of the same color but, if we provided a separate color for every individual wire for every individual purpose, not enough colors would be available.

ENGINE DIVISION

FLYWHEEL HOUSINGS
(*Proposed Revision of Present S.A.E. Standard,* p. 10)

CRANKCASE DRAIN-PLUGS
(*Proposed Revision of Present S.A.E. Standard, p.* 12)

IRON AND STEEL DIVISION

STEELS 2015 AND 2115
(*Proposed S.A.E. Standard, p.* 12)

STEEL 1046
(*Proposed Revision of Present S.A.E. Standard, p.* 13)

ROCKWELL HARDNESS-TEST
(*Proposed S.A.E. Recommended Practice, p.* 13)

STEELS 4130, 4140, 4615—HEAT-TREATMENTS
(*Proposed General Information, p.* 14)

LIGHTING DIVISION

HEAD-LAMP STRENGTH AND RIGIDITY
(*Proposed Extension of Present S.A.E. Recommended Practice, p.* 16)

BASES, SOCKETS AND PLUGS
(*Proposed Revision of Present S.A.E. Standard, p.* 16)

TAIL-LAMP SPECIFICATION
(*Proposed Revision of Present S.A.E. Recommended Practice, p.* 17)

MOTOR-TRUCK DIVISION

Midship Shaft-Mounting

(*Proposed S.A.E. Recommended Practice, p.* 18)

THE DISCUSSION

A. J. Scaife:—I have a letter from Mr. Stone, mechanical engineer of the Merchant & Evans Co. He says:

> We note that it is intended to use a certain-diameter bearing for each size of tubing. Our practice has not agreed with this, and we are doubtful whether it would hold in the future. The 309 bearing is the largest we have ever used for sizes of tubing up to 3 in. in diameter. We have, at times, put 3-in.-diameter tubing on shafts, using bearings as small as 307. Aside from these few comments, we are satisfied with the arrangement.

A letter from Ernest Wooler, chief engineer of the Timken Roller Bearing Co., says:

> I really feel that the three-joint propeller-shaft construction is mechanically wrong and that we should have a four-joint construction with a rigidly supported center-shaft with the first and third shafts floating. The fact that there seems to have been considerable question regarding the use of a self-aligning bearing and there is a bearing in the housing is evidence that there is doubt on this subject.

A letter from Mr. Myers, of the engineering department of the Service Motors Co., states:

> The overhang from the bearing to the flange is too great to give satisfactory results. The numerous diameters given will add considerably to the cost of the manufacture. The design is practical only with metal joints in front of this arrangement. No consideration whatever is given to the use of fabric disc joints. The use of an oil-flinger such as is recommended will result in difficulty, both in assembly and in service after the front joint of the shaft begins to wear slightly.

PARTS AND FITTINGS DIVISION

Flexible-Disc Tolerances

(*Proposed Revision of Present S.A.E. Standard, p.* 19)

Rod-End Pins

(*Proposed Revision of Present S.A.E. Standard, p.* 19)

Rivets

(*Sectional Committee Report Proposed for Approval by the Society as Sponsor, p.* 19)

This report was submitted for approval as tentative American Standard by the Society as a sponsor for the Sectional Committee on Bolt, Nut and Rivet Proportions, which was organized under the procedure of the American Engineering Standards Committee. The report was not submitted at this meeting for approval as an S.A.E. specification.

THE DISCUSSION

A. Boor:—With regard to that part of the report relating to Tinners', Coopers' and Bolt Rivets printed on pp. 21 and 22, the Division does not feel that these should be accepted because the body diameters are given to only two decimal places, while tolerances are given to three decimal places. The body diameters of the rivets are the important dimension. Further, these tables are not consistent with the tables for small rivets in the report we have already approved. Another reason for the Division's objection to the report is that the wording in the notes therein is not clear and concise.

PRODUCTION DIVISION

T-Slots, Bolts, Nuts and Cutters

(*Sectional Committee Report Proposed for Approval by the Society as Sponsor and as Proposed S.A.E. Standard, p.* 34)

This report was submitted for approval as tentative American standard by the Society as a sponsor for the Sectional Committee on Small Tools and Machine-Tool Elements, which was organized under the procedure of the American Engineering Standards Committee. The Division, in recommending its approval as such, also recommended that the report be approved for adoption as an S.A.E. Standard for production machinery.

SCREW-THREADS DIVISION

High Nuts

(*Proposed Revision of Present S.A.E. Standard, p.* 23)

Cap-Screws, Bolts and Nuts

(*Proposed Revision of Present S.A.E. Standard, p.* 23)

Plow Bolts

(*Sectional Committee Report Proposed for Approval by the Society as Sponsor,* p. 23)

Round Unslotted-Head Bolts

(*Sectional Committee Report Proposed for Approval by the Society as Sponsor, p.* 27)

These two reports were submitted for approval as tentative American Standards by the Society as a sponsor for the Sectional Committee on Bolt, Nut and Rivet Proportions, which was organized under the procedure of the American Engineering Standards Committee. They were not submitted for approval as S.A.E. specifications.

THE DISCUSSION

E. H. Ehrman:—With your permission, we will consider the reports on Plow-Bolts and the Round Unslotted-Head Bolts as one item for the reason that the same points and features are involved in both. The Society is co-sponsor with the American Society of Mechanical Engineers for the Sectional Committee, appointed for the national standardization of bolts, nuts and rivets.

The Division recommends that these proposed tentative American Standards be accepted as to all details, with the exception of the tables for thread and body lengths. In the original organization of the Sectional Committee, a sub-committee was appointed to report on body dimensions and tolerances, including dimensions for the diameter, shape of point, length of thread, and the like. This subcommittee did not function. Some of the other subcommittees have established dimensions for the heads only, leaving it to this subcommittee, or some other group, to set those dimensions that are common to the various type of bolt, such as length of thread, body diameter, tolerances, and shape of point. There is some controversy at the present time with regard to the action of another subcommittee in recommending thread lengths, shape of point and similar dimensions for slotted-head cap-screws and machine-screws. That subcommittee is, I believe, receding from its position and is showing willingness to leave several of these points open, merely printing them with the specifications as a matter of information.

The matter of standardizing body lengths is a different one entirely and would, perhaps, be a distinct handicap. If they are over-standardized, it means that the various lengths will be manufactured and kept in stock, to be sold on a list and discount basis as regular goods when demand may not warrant their being kept in stock. On the other hand, if standardization is limited, it may not cover the whole field. As a matter of fact, most of the trade organizations with which I am acquainted believe that the matter of standardizing lengths belongs to the selling branch of the business and that the catalogs of the various companies belonging to these trade organizations will show uniformly and definitely what lengths it is desirable to carry in stock as samples, all others being special. For these reasons the Division has not recommended the approval of the tentative standards proposed under the headings of Plow-Bolts and Round Unslotted-Head Bolts so far as thread and bolt lengths are concerned. May I stress this point? There is no objection to including the tables of thread lengths and body lengths as recommended practice or information. The point is that they should not be advanced to the status of a standard at this time.

Set-Screw Heads and Jam Nuts

(Proposed S.A.E. Standard, p. 32)

Slot and Cotter-Pin-Hole Dimensions

(Proposed Revision of Present S.A.E. Standard)

This report relates to a refinement of the standard that was printed on p. C3a of the S.A.E. Handbook, issued last September, and was not printed in the January issue of The Journal, inasmuch as the necessary dimensions had not been worked out and approved by members of the Screw-Threads Division until shortly before the meeting of the Standards Committee. The complete table in which the dimensions reported will be included is printed herewith in the form in which it will appear in the March issue of the S.A.E. Handbook if approved.

SLOT AND COTTER-PIN-HOLE DIMENSIONS

Cap-Screw and Bolt Nominal Diameter, In.	Cotter-Pin Hole Diameter, In.	Head Slots Width, In.	Head Slots Depth, In.	Center of Cotter-Pin Hole to Extreme Point of Screw,[1] In.
1/4	5/64	1/16	3/32	7/64
5/16	5/64	1/16	7/64	1/8
3/8	1/8	3/32	1/8	5/32
7/16	1/8	3/32	1/8	5/32
1/2	1/8	3/32	1/8	11/64
9/16	5/32	3/32	1/8	3/16
5/8	5/32	3/32	1/8	3/16
3/4	5/32	3/32	1/8	7/32
7/8	5/32	3/32	1/8	1/4
1	5/32	3/32	1/8	1/4
1⅛	7/32	5/32	7/32	9/32
1¼	7/32	5/32	7/32	9/32
1½	1/4	3/16	1/4	5/16

[1] It is suggested that this dimension be used to determine the distance from the cotter-pin hole to the under-face of the head of the screw or bolt.

THE DISCUSSION

Mr. Ehrman:—The Division submits an additional report that was not printed in the January issue of The Journal which relates to the dimensions in column *M*, on p. C3a of the S.A.E. Handbook, giving the distance from the center of the cotter-pin hole to the end of the bolt as measured along the side to where the rounding begins; that is, not to the extreme end. The form of the end of the bolt in the standard is being changed from a rounded point to a flat and chamfered end, and the length of the bolt is to be measured to the extreme end, instead of to the base or edge of the rounded point as in the past. This makes it necessary to add an increment to the dimensions in column *M*. This has been done, samples have been made as a check, and the Division recommends the adoption of this revision. The omission of this from the table was not observed at the last meeting of the Screw-Threads Division. The matter has been taken up by the members since that meeting, and approval of the change has been unqualified.

Wrench-Head Bolts and Nuts and Wrench Openings

(Proposed Revision of Sectional Committee Report)

This report by the Division relates to a considerable number of minor changes in the report of the Sectional Committee, for which the Society is the sponsor, that was approved and adopted in part by the Society last June. The report was not printed in the January issue of The Journal because of the great number of detailed references that would have been necessary in a printed report. Copies of the revised report that were furnished by the Secretary of the Sectional Committee were sent to the members of the Division, together with a complete list of the proposed changes, prior to the meeting of the Division at which the revision was approved. The Division submitted this report at the Standards Committee Meeting as a formal step in the procedure of the Society in the adoption or revision of Sectional Committee Reports. Those who may desire detailed information regarding these changes may secure it by communicating with the Society's Standards Department.

THE DISCUSSION

Mr. Ehrman:—The Division submits for approval a number of slight changes in the report, as approved and adopted by the Society last year, that it has been found wise to make since then. These changes are not material and relate in most part to slight modifications in the third place of decimal figures in the tables and to the phraseology of the notes appended to them, and are made as a refinement of the standard.

TRANSMISSION DIVISION

Clutch Nomenclature

(Proposed Revision of Present S.A.E. Standard, p. 38)

REPORTS APPROVED AS AMENDED

The reports that were approved at the Standards Committee Meeting in amended form follow, the principal discussion in each case being given.

ENGINE DIVISION

Engine-Testing Forms

(Proposed Revision of Present S.A.E. Standard, p. 10)

The paragraph relating to Correction Factors was amended to read:

> If it is desired to correct the results, a standard barometric pressure of 29.92 in. of mercury and a standard temperature of 500 deg. fahr. absolute, which is the same as 60 deg. fahr., shall be used in making the corrections.

THE DISCUSSION

H. M. Crane:—I move that the report be amended by the rewriting of the paragraph on Sheet A of the Testing Forms, relating to Correction Factors, to read: "If it is desired to correct the results, a standard barometric pressure. . . ." The temperature correction cannot be trusted in the case of many engines except over a very narrow range of correction, and there is no reason for requiring that corrections should be made. A great many engineers prefer to get the report with the temperatures and barometric pressure stated and then form their own conclusions as to what would happen under different conditions.

LIGHTING DIVISION

Signal Lamps

(Proposed Revision of Present S.A.E. Recommended Practice, p. 16)

The color of the lamp glass was changed from red to amber.

THE DISCUSSION

Mr. Crane:—Committee 7 of the National Conference on Street and Highway Safety, as instituted by Secretary of Commerce Hoover, went into the whole question of automobile rear-lamp lighting. At that time a strong effort was made to have the tail-light color made yellow instead of red. The industry did not wish to depart from the red tail-lamp and maintained that the existing standard practice should be continued. The reason for adopting yellow in the case of the rear signal-lamp is very plain. It is only a signal-lamp and is not a stop-lamp; it is simply to notify a car driver behind that a driver in front is applying the brakes; it is a warning-light. The yellow light on a railroad means: be prepared when a red light is reached. With a red tail-light on a motor-car and a yellow signal-light indicating the application of the brake, we have the same combination, which is what we want. I think that to have the same color for signal-lights as for tail-lights is wrong. At present the tail-light is also the parking-light and definitely should be red, like any other light on a stationary obstruction in the street. I think the proper color for a

signal-light is yellow, as long as the tail-light of the car is to be red. Having explained my position, I would like to suggest that the color in this case be changed from red to yellow, or rather to amber, which is a more correct term for what is actually used as a cautionary signal by railroads.

MR. SCAIFE:—What action has the Eastern Conference of Motor-Vehicle Administrators taken on the matter of enforcement? It seems to me that some States, particularly Connecticut and Massachusetts, require yellow.

C. A. MICHEL:—To my knowledge no effective enforcement of color regulations is made in any of the States. I would like to suggest that, in view of the fact that this report covers largely lighting intensity and distribution, we vote on this recommendation, omitting red, and refer the matter of color back to the Division for further consideration.

MR. CRANE:—I would be willing to leave the question of differentiation of color to the Division, but I feel strongly that the tail-light color should be different from the signal-light color, regardless of what either may be.

R. N. FALGE:—I think it is much more important that we specify some color than that we standardize on either red or yellow. There is no standardization at all, and we should have a definite color.

MR. CHURCHER:—I agree with Mr. Crane that red should remain as the tail-light color. Amber is more suitable for a stop-signal than any other color, it is more generally used than green, and it will show-up to better advantage.

AZEL AMES:—I thought red always stands for stop and yellow for caution. We should make them stand for these two things only, and not change their meaning.

CHAIRMAN F. A. WHITTEN:—The motion before the meeting is that the report be approved with the color of the signal light changed from red to amber.

MR. CRANE:—Amber is the more correct designation, as was determined by careful tests. It should be definitely differentiated from an ordinary oil-lamp color, which gives rather a yellow light. The railroads' yellow lights are a yellowish brown, or a brownish yellow, which is called amber. They had to develop a yellow more definitely different from the yellow oil-light, and that is what they call amber.

ELECTRIC INCANDESCENT LAMPS

(*Proposed Revision of Present S.A.E. Standard, p.* 17)

The tolerance given in footnote (1), under the table on p. 18 of the January issue of THE JOURNAL was changed from the decimal 0.047 in. to the equivalent fraction 3/64 in.

THE DISCUSSION

MR. MICHEL:—One detail of this report has aroused considerable discussion. Heretofore the tolerance on filament placement has been expressed in common fractional form as plus or minus 3/64 in. In the revised report this tolerance has been changed to the equivalent decimal 0.047 in. To specify the tolerance as 0.047 in. indicates a finer degree of accuracy in measurement than is possible at present, and a value beyond the second decimal place is superfluous. Recently, the State of Massachusetts has proceeded to approve electric incandescent lamps for automobile use having a tolerance of plus or minus 0.050 in. which is 0.003 in. greater in each direction than specified in the report. Those on one side of the argument point out that adopting a standard here that is different from that of the Massachusetts specification would establish two standards unnecessarily. From the Society's standpoint, it is pointed out that it does not formulate standards on the same basis that a State would. The Society's standards are based on engineering practice, whereas the State's specifications are based on maximum regulatory requirements. If we accept the suggestion not to go beyond the second decimal place, it would be necessary to adopt a standard of either 0.05 or 0.04 in., and I believe 0.04 in. is not satisfactory to the electric incandescent lamp manufacturers. They are progressing toward that end but it would be dangerous to incorporate that figure as a S.A.E. standard at the present time.

B. M. SMARR:—I do not believe that a tolerance of plus or minus 0.047 in. indicates any particular degree of accuracy. Some difficulty may be encountered in measuring to thousandths of an inch in this case but I am opposed to increasing the amount of the tolerance.

MR. MICHEL:—I take it that all of the electric incandescent lamp manufacturers are satisfied with the report as it stands inasmuch as no opposition is presented. In view of this, I move that the report be approved.

MR. FALGE:—I suggest that the report be approved, omitting the tolerance on the filament placement until such time as the industry is better able to reach agreement, especially with the State authorities, in this connection.

D. A. HARPER:—As the representative of an electric incandescent lamp manufacturer I believe that a tolerance of plus or minus 0.04 in. would be satisfactory, and if the Committee feels that it wants to specify this tolerance, I would be willing to approve it.

MR. MICHEL:—Are there any objections to letting the standard remain as it was before; that is, to give the tolerance as plus or minus 3/64 in. There is the necessity of having something established and this would not conflict or establish a precedent. I suggest that as an amendment to the motion for appproval.

CHAIRMAN WHITTEN:—We have compromised on the report as it stands, by changing the tolerance on dimension *C*, as given in footnote 1 of the report, back to the original plus or minus 3/64 in.

TRANSMISSION DIVISION

CLUTCH FACINGS

(*Proposed Revision of Present S.A.E. Recommended Practice, p.* 38)

The footnotes referring to thickness tolerance were amended to state that the tolerance specified does not relate to the parallelism of the lining faces.

REPORTS REFERRED BACK TO DIVISION

The following reports were referred back to the Electrical Equipment Division for further consideration, in accordance with discussion at the meeting of the Standards Committee, the pertinent parts of which are printed herein after each of the subjects.

ELECTRICAL EQUIPMENT DIVISION

DISTRIBUTOR-ROTOR ELECTRODE

(*Proposed Extension of Present S.A.E. Standard, p.* 8)

This subject relates to the standard for automobile nomenclature.

THE DISCUSSION

MR. CHURCHER:—I suggest that the words "load-limit controller" be changed to "load limitor," and that the term "voltage regulator" be changed to "charging controller," because the Charging Controller contains three elements, the voltage regulator, the load limitor and the cut-out relay.

MR. LEE:—I would not want to standardize on a word that is not in the dictionary.

MR. CHURCHER:—"Load Limitor" is more descriptive of the article and "load-limit controller" is too long.

MR. LEE:—Would it not be desirable to let the matter of standardizing this term rest for a year and see what the service stations eventually use. This apparatus is used only on motorcoaches at this time.

C. F. CLARKSON:—If a suitable term can be decided on now before the terminology of the trade becomes diversified, it would be well to do this. We know that if a term becomes prevalent in the trade, it is difficult to inject another term for the same thing into use.

MR. CHURCHER:—That is the reason I think we should adopt a name for it now. Then everybody will use it.

CHAIRMAN WHITTEN:—In connection with the proposed change in the name of the voltage regulator, it seems to me that that particular term is now in rather common use, although perhaps it is confusing.

MR. CRANE:—I do not see how a member of this Committee

could vote intelligently on this report as a result of the discussion up to this time. The report should go back to the Division for further consideration and be brought to a subsequent meeting of the Standards Committee.

[On motion, duly seconded, it was voted to refer the report back to the Electrical Equipment Division for further consideration.]

GROUND-RETURN WIRING SYSTEM

(Proposed Revision of Present S.A.E. Standard, p. 8)

THE DISCUSSION

MR. CRANE:—When I looked over this report, it seemed to me that it was about 12 years old because it dates back to the time when a good many men on the Standards Committee were in favor of making the then S.A.E. Standards Book an engineering handbook. Any reading of this report indicates obviously that 90 per cent of it is not material for standardization. The recommendation is very general and not specific. For instance, nothing definite is said about the wiring installation; there is a generalization, a statement of what is probably good engineering practice and not a standard in any sense of the term. The general opinion of the Standardization Policy Committee has been that it is far better not to have this class of specification in the S.A.E. HANDBOOK because it detracts from the strength of the standards and does not add anything of particular value. Like all engineering practice, it varies with the elements we have to work with, such as the kinds of battery used and the cases they are mounted in.

MR. LEE:—Sufficient information that will be of benefit to the car builders is contained in the report, but it is true that some of it could be left out.

J. H. HUNT:—I am inclined to subscribe to what Mr. Crane says. The report looks like desirable engineering practice, but changes in valuable equipment or materials may make it desirable to use something different. Another possibility is that regulatory authorities and others might cite such specifications against a proposed new and perfectly justifiable practice.

MR. CRANE:—I want to emphasize that the S.A.E. HANDBOOK is not the place for this sort of specification because it does not deal with definite factors. I think the S.A.E. HANDBOOK should give facts rather than opinions. This kind of report is bound to be a small percentage of fact and a large percentage of opinion. I think the Division has done excellent work and possibly the Society should publish this report in pamphlet form or in THE JOURNAL, but I think the S.A.E. HANDBOOK is not the place for it.

MR. CHURCHER:—The reason we did all this work was that the S.A.E. Standard adopted in 1914 is completely outofdate and we feel that some general specifications should be given in the S.A.E. HANDBOOK that will promote standardization in wiring. The proposed standard is subject to revision from time to time; any suggestions toward that end will be duly considered and acted upon.

MR. CRANE:—I am not criticizing this report as a specification for someone to adopt personally in building an automobile, or for use in modified form if he wishes, but it is altogether impossible to say that it states the only way to make a good installation. In a number of instances in the report no definite information is given as to what is and what is not good procedure. For instance, the untrained man cannot install a battery according to this specification and know that an overflow of electrolyte from it will not cause an appreciable leakage of current. How will he know some of the other things we find in the report, such as "each compartment shall be provided with an independent cover, ventilation and drainage"? Nobody who is not a properly qualified engineer could use this specification. My original point was that a really good standard for the Society to accept is not merely a matter of engineering opinion.

We have today in this meeting two diametrically opposite points in view. The Aeronautic Division has recommended the removal of several items from the S.A.E. HANDBOOK on the very basis I am speaking of, stating that in their opinion standardization should relate to interchangeable dimensions.

MR. LEE:—I think we can overcome the objections if we recommend that this revision be adopted as S.A.E. Recommended Practice rather than an S.A.E. Standard. To withdraw this valuable information from the S.A.E. HANDBOOK until we provide some other means of getting it to the members would be a mistake. I move that this specification be approved as S.A.E. Recommended Practice.

MR SCAIFE:—I wonder if we are not confusing this matter of standards. The theory of the Society has been that standards follow and never precede general practice. While this is a good specification that should be known to the trade, I question whether we are ready to adopt it as S.A.E. Recommended Practice.

CHAIRMAN WHITTEN:—Apparently, agreement is lacking as to the matter of policy with relation to some of the details of the report. We have a motion before the Committee, which has been seconded, that the report be adopted as S.A.E. Recommended Practice. Should that be defeated, it will be in order to refer it back to the Division and ask for a policy recommendation from the Standardization Policy Committee.

MR. LEE:—In view of the discussion and the fact that a question of policy is involved, I wish to withdraw my motion that the specification be adopted as S.A.E. Recommended Practice, and now move that the report be referred back to the Division for further consideration in conjunction with the Standardization Policy Committee.

[The motion was seconded and carried.]

The action of the Standards Committee was reported by Chairman Whitten to the Council in the afternoon and approved. The action was similarly approved at the Business Session of the Society in the evening and ordered to letter-ballot of the Society members for final action.

ATTENDANCE AT STANDARDS COMMITTEE MEETING

The members of the Standards Committee and the Society members and guests in attendance were:

Standards Committee Members

Azel Ames
N. G. Anderson
B. B. Bachman
G. E. Bechtel
A. Boor
G. R. Bott
L. R. Buckendale
R. S. Burnett
W. B. Churcher
C. F. Clarkson
E. H. Ehrman
B. V. Evans
R. N. Falge
A. R. Fors
Charles Froesch
D. E. Gamble
D. A. Harper
J. D. Harris
H. P. Harrison
E. J. Janitzky
L. P. Kalb
O. C. Kavle
P. J. Kent
C. M. Larson
T. L. Lee
B. M. Leece
G. L. McCain
R. C. McWane
A. F. Milbrath
S. W. Mills
W. J. Outcalt
D. W. Ovaitt
O. A. Parker
H. N. Parsons
E. N. Sawyer
A. J. Scaife
A. A. Schupp
B. M. Smarr
C. W. Spicer
F. C. Stanley
A. J. Underwood
R. H. Upson
C. B. Veal
George Walther
J. M. Watson
F. A. Whitten
F. G. Whittington
T. H. Wickenden
Ernest Wooler
G. A. Young

Society Members and Guests

Robert Atkinson
D. Beecroft
C. C. Bohner
S. R. Castor
D. S. Cole
E. A. Cousins
E. B. Denison
H. C. Dickinson
S. R. Dresser
William Dunk
R. A. Follensby
H. E. Fromme
J. C. Geniesse
R. W. Gibson
Russell Hoopes
W. M. Horton
W. A. Johnston
D. F. Kalish
Robert Lapsley
B. J. Lemon
C. F. Loew
F. H. Longyear
B. F. Marty
L. H. Nagler
Charles Pleuthner
E. J. Riordan
J. W. Saffold
F. W. Sampson
G. M. Satterfield
S. W. Sparrow
M. J. Steele
W. C. Thee
W. G. Wall
C. B. Whittelsey
M. J. Zurrow

THE 1927 ANNUAL MEETING

(*Concluded from p.* 192)

Small French Cars

An outline of his experience with some of the early types of small French car was given by L. Melanowski, who said that the small light-car presents a very difficult problem for the engineer. He remarked that the first development in France was the small car, but that this car has gradually become a large car, one reason being the excellence of the French highways. This influence of the highways is also one factor that makes the problem of the American light-car different from that of the French light-car. In his opinion, the decision of definite specifications for the American small light-car will be evolved as a result of conference between capitalists, engineers and salesmen, following determination of where the market lies for the product, what the price is and what the road conditions are. These factors will determine whether the small light-car can be made successful.

WHAT WAS THE MYSTERY?

Answer May Be Found in Remarks of the All-Star Presidential Cast

The power of attraction of a galaxy of stars was exemplified when 380 members and guests assembled for the Mystery Session of the Annual Meeting on the afternoon of Jan. 27, the best attended technical session of the meeting, notwithstanding that no bill of the performance had been announced. Not even the performers themselves knew in advance of the session what kind of an act it was to be and what topics were to be presented and discussed. Unfortunately three of the attractions on the bill were unable to be present and play their parts. These were H. W. Alden, H. L. Horning and A. L. Riker.

Coker F. Clarkson, who officiated as stage director, said that notoriously all-star casts mean trouble but that if anybody can maintain an all-star cast satisfactorily perhaps it is the Society of Automotive Engineers. He did not know, he said, what the presidential luminaries of the relic type were going to do or say, for although they had told him all that he knew about the subject, they had not told him all that they themselves knew about it. Only he who knows what has happened in the past can understand what is going to be, he said, and with these preliminary observations he called first on C. F. Kettering, of whom it has been said that his great achievements were brooded in long night vigils, which Mr. Clarkson thought might be so, as he had never seen Mr. Kettering doing any work in the daytime.

Symposium on What You Like

He was put on first in the vaudeville act, said Mr. Kettering, to open it with an acrobatic performance until the room filled up and then, when he got through and the confusion died down, the intelligencia would come on and have the air of an operatic recital. "This is supposed to be a symposium of anything you want to talk about, as most symposiums are," he said, so in opening it he talked about thoughts stimulated by a meeting of the Technical Committee of the Oil Conservation Board that had visited the General Motors Corporation Research Laboratories during the day "to investigate what we are going to do about oil when we have no more." Twenty million motor-vehicles operating in the Country last year consumed approximately 9,000,000,000 gal. of fuel and the consumption will perhaps increase to 10,000,000,000 or 11,000,000,000 gal. this year. The question is, therefore, what can be done to get more work out of the fuel or to look for other sources of supply. Practically anything that is done to help economy also helps performance, he said; in other words, we are on the eve of the introduction of the high-compression engine. We are starting on the long line of development to get an improved engine with from 25 to 35 or 40 per cent increase in economy.

After mentioning the conversion of coal into liquid fuel by hydrogenating and synthetic processes and the introduction of the Diesel-type engine for rail cars, Mr. Kettering said that an automobile race open only to cars driven by oil engines is to be run at Indianapolis some time next fall to stimulate interest in the use of lower-grade fuels.

Fittest in Transportation Will Survive

Thomas J. Litle, Jr., president of the Society, reviewed briefly the development of transportation in civilized countries, as during the last 100 yr. in the United States. The better the transportation the more prosperous and greater a country is, he said, and recalled how this Country developed when the steam railroads followed the prairie schooner. He commented on the preference of the public for the more comfortable traveling by steamship at night than in sleeping-cars and said that when selling to the public it is necessary to give the people what they want. He then told of the paralleling of the railroads by electric railways with their lower rates, and later the competition of motor-coaches with both types of rail transportation. In the great transportation system, said Mr. Litle, he sees merely a case of the survival of the fittest.

Some Things for Engineers to Think About

Some thoughts left with the audience by Past-President David Beecroft, of the Chilton-Class Journal Co., were that engineers should give more thought to ways of increasing safety on the highways congested by 22,000,000 motor-vehicles, making the cars less fatiguing to the woman driver, and easier to repair in the service stations by greater accessibility of the component parts and by using information that can be gathered from cars competing in automobile races to improve the efficiency of engines and chassis.

He said he thought that the Society should have a standing committee to make a complete study perhaps annually of the flat-rate systems in service stations and repair shops and the relation that exists between them and the matter of accessibility. He also said that he should like to see a committee appointed which would be representative of the different factors in the automobile industry to be present at the Indianapolis races to bring forth from the contests a very clear picture of the engineering developments to present to the Society at its meetings and in its publications.

Lion and Lamb Lie Down Together

B. B. Bachman, of the Autocar Co., reminisced a bit in Society history to show the change in attitude of the railroads toward motorcoach and motor-truck transportation from 1923 to the present time. In the post-war period the discussion of highway transportation in competition with transportation by rail assumed an acrimonious phase in some of its aspects, he said, with the interests associated with highway transportation taking one side and those associated with rail transportation the other. Since that time, however, as reflected in recent meetings of the Society, the railroads have accepted the fact that a field for highway transportation exists and at present 6500 companies are operating 25,000 motorcoaches and of these 339 electric railway companies operate 6500 motorcoaches.

Mr. Bachman recalled the biblical reference to the lion and the lamb lying down together and said he had heard a remark in connection with the railroads and motor-vehicles that the simile might be carried farther and that the two would rise together but with the lamb inside of the lion. Probably some justification exists for such a thought, he said, but he believes that the recognition of the importance of highway transportation by the railroads is a valuable contribution to transportation economics and has indicated

THE CHAIRMAN AND SPEAKERS AT THE MYSTERY SESSION

From Left to Right They Are B. B. Bachman, President 1922; H. M. Crane, President 1924; David Beecroft, President 1921; Coker F. Clarkson, "The Dean of the School of Presidents"; T. J. Litle, Jr., President 1926; J. H. Hunt, President 1927; J. G. Vincent, President 1920, and C. F. Kettering (insert), President 1918

that no such sharply defined competition prevails as is ordinarily associated with the use of that term.

He spoke of the relation between the growth of communities and the use of motor-vehicles and the resulting condition of highway congestion which has brought problems that are difficult to solve. In addition to studying the necessity for smaller vehicles, the rearrangement of highways and better planning of cities, he thought that consideration probably would have to be given to the decentralization of our activities and if these things happen a still further increase in demand for transportation will be found.

ENGINEERS MUST BE OPEN-MINDED

One wonderful thing about the automotive industry is the ready way in which it absorbs its mistakes, said J. G. Vincent. We go merrily on our way, sometimes in a circle, but always forward. Perhaps we started out building cars low and when they got hung up on a rock in the middle of the road we decided we wanted more ground clearance and raised the car. Then someone built an underslung job that looked like a German dachshund and down the cars went. Twenty years ago tires gave real trouble and the time to retire might be any time. When tires and roads were improved and the cord tire was perfected, tire troubles were forgotten until the tire manufacturer upset the applecart and started us all working over again with balloon tires. Another example of reversion to the primitive occurred with ignition. Early automobiles were equipped with battery ignition, then magnetos were adopted to get away from battery troubles until Mr. Kettering evolved a self-starter and a return to battery ignition followed.

The speaker gave corresponding examples in the aeronautic field, mentioning the biplane as the first successful flying-machine used by the Wright brothers, then the swing to the French monoplane type, next the victory of the biplane in the Pulitzer races at Detroit a few years ago, and finally the breaking of the world's speed record with a monoplane. C. M. Manly built the first radial water-cooled aircraft engine but the Wright brothers used an upright water-cooled engine and for years the latter type was highly developed but now the air-cooled radial type is in favor.

Lessons to be learned by the younger engineers from such examples of backing and filling, said Mr. Vincent, are to preserve a spirit of tolerance, to adopt a policy of reasonable conservatism, to cultivate a stout heart, and be prepared to hear that some rival has rediscovered a principle that was unearthed years ago. The successful automotive engineer must be unbiased and unprejudiced in viewing innovations.

CALLS FOR IMAGINATION IN ENGINEERING

When Henry M. Crane arose he presented Coker F. Clarkson to the audience as the "dean of the S.A.E. presidential school", saying that he thought the Meetings Committee justly believed there was only one man in the organization who could control a session of the Past-Presidents. The thought that Mr. Crane had in mind, he said, was to present a call for the use always of more imagination in engineering work and cited as a conspicuous example the imagination of Henry Ford as exemplified by his foresight that the automobile would become a commonplace of daily life. On a recent trip abroad he was impressed that the condition which Mr. Ford exploded some years ago in this Country still exists in Great Britain and on the Continent, where many families that can afford motor-cars of the light type that Alan Fenn had described at the Light-Car Session fear to make the purchase because it would lead their friends to think that they were "putting on a lot of front".

Imagination in engineering really divides the true engineer from the copyist who can look only backward or at most sidewise. The real engineer is living in the future and preparing for what is to come even though he cannot foretell exactly what it may be. The speaker gave a few instances of the necessity of such imagination as related to testing new designs and the designing of new models that will meet the wants of the possible customer before he has become conscious of any such want. The organization with which he is connected, he said, feels that the greatest thing the industry can do is to make the use of automobiles as economical as possible, with the inevitable result that more of them will be used. Engineers owe it to their self-respect to make a much more definite attempt to make every part of the motor-car readily accessible so that the cost of operation can be reduced to the minimum and the useful hours on the road increased. The automobile should be gone over

at least once a year with a fine-tooth comb, he said, and the questions asked, "What is this part for?" and "Does this part do the work in the best possible way and to best advantage?"

Artificial Restrictions on the Engineer

President-Elect John H. Hunt spoke of the beneficial and detrimental restrictions that surround the engineer, saying he had known of developments by engineers that had had to wait from 2 to 8 years until the factory management was willing to change the tool line-up to produce a slightly different design. With the competing situation developing as it is, he said, he thought it would be possible for the engineer to influence that condition. It is better, he said, to travel a spiral course like that in the industry referred to by Mr. Vincent than to have designs petrified by the retention of old methods. Standards restrict the engineer to some extent but so long as many are available to choose from the industry will not be confined to anything that will not fit in with any reasonable progressive program.

He spoke of the effect of legal restrictions on the design of British and Continental cars and said the disposition to interfere with the engineer is increasing, and urged engineers to use their influence to show how proposed restrictions would handicap development. Artificial restrictions caused by labor regulations can become harmful, he said, and referred to efforts made in certain States to pass laws against the use of certain tools or processes rather than the elimination of any evils that might be inherent in the particular process. He referred to the constructive work done by the Underwriters' Laboratories in calling attention to the fact that certain structures had proved to be very successful in service while others had been unsuccessful and the system of encouragement of satisfactory construction by preferential insurance rates. He warned, however, against a disposition by some to carry this work too far by attempting to predict what will happen from an untried design and to influence the design, saying that the guess of an engineer in one laboratory is not necessarily better than that of another engineer in some other laboratory.

Another example of restriction is the various State headlighting regulations which threaten to interfere seriously with car equipment because the authorities who wish to accomplish something toward the reduction of highway accidents are attempting to specify the means rather than the result. The automobile industry developed rapidly in this Country because the engineers were not tied down with legal restrictions and were free to use their brains and, by successively trying various ideas, secure results that possess value.

THOUGHTS ON SUMMER MEETING

Committee Suggests Session Topics; Acts on Dates and Places of Others

Members of the Society who attend the Summer Meeting will be amply instructed through the eye as well as through the ear, according to the tone of the discussion at the Meetings Committee Dinner Meeting that was held on Jan. 27. This was a combined gathering of the 1926 and 1927 Meetings Committee personnel, presided over by T. J. Litle, Jr.

During the meeting the discussion returned a number of times to the advisability of supplementing written and presented papers with exhibits and demonstrations. Citing as an example of the success of such visual adjuncts, the interest shown at the 1926 Summer Meeting in the headlighting demonstration, the members of the Committee were agreed as to the advisability of arranging for as many of these show features as possible.

While no final action was taken in assigning subjects for sessions, enough interesting suggestions were made to form a basis from which to select topics that will assure attractive meetings and active discussion. One thought to which considerable attention was given was to have a session devoted to the stationary internal-combustion engine of the type now being used to such a great extent in building operations and other similar powerplants. The industrial tractor, including such equipment as that used in snow removal, was also advanced as a good topic. Both of these subjects represent fields a little outside that on which the Society has recently concentrated and will, if included on the program, broaden the scope of its activities and interest. Among the large number of other topics mentioned were superchargers, the high-speed Diesel engine, the high-speed versus the low-speed engine, wind resistance of motor-vehicles, special tourist bodies, and a thorough analysis of a motor-car, including such parts as tires, springs and similar elements treated as part of an elastic system.

It is too early to speak with authority on the lighter side of the Summer Meeting, but it is safe to say that certain stunts are in the wind that promise to afford drama and comedy for all concerned.

The question of the place of the Summer Meeting again came up for discussion. After hearing a report of the opinion registered by the Sections Committee at its meeting on the previous evening and canvassing the merits of various suggested localities, the members of the Meetings Committee present endorsed by a unanimous vote the selection of French Lick Springs. In a second poll of all present, only one adverse vote was cast.

Action was taken toward fixing the time and place of the various national meetings. The Aeronautic Meeting will be held, as usual, in connection with the National Air Races. The Production Meeting will be held during the week of Sept. 19, the place to be decided after hearing the recommendation of the Production Committee. The Transportation and Service Meeting will take place in the early part of November, at Cleveland, the exact time to be decided later. The Tractor Meeting will be arranged to coincide with the meeting of the American Society of Agricultural Engineers. As usual, Thursday of the New York Automobile Show week is reserved for the Annual Dinner. The Annual Meeting will take place in Detroit, at the same time with reference to the Chicago Automobile Show as this year, and the night for the Carnival was fixed, as for this year, as that following the last technical session.

UP-TO-DATE TRANSMISSION-PRACTICE

Four-Speed Transmissions and the Constantinesco Torque-Converter Considered

Nearly 250 members and guests attended the Transmission Session that was held on the morning of Jan. 28. The paper on Four-Speed Transmissions, by C. A. Neracher and Harold Nutt, of Durant Motors, Inc., is printed in full elsewhere in this issue of THE JOURNAL, and it is expected that the second paper, on the Constantinesco Torque-Converter will be printed in a subsequent issue. Herbert C. M. Stevens, consulting engineer for the Olds Motor Works, Lansing, Mich., was chairman.

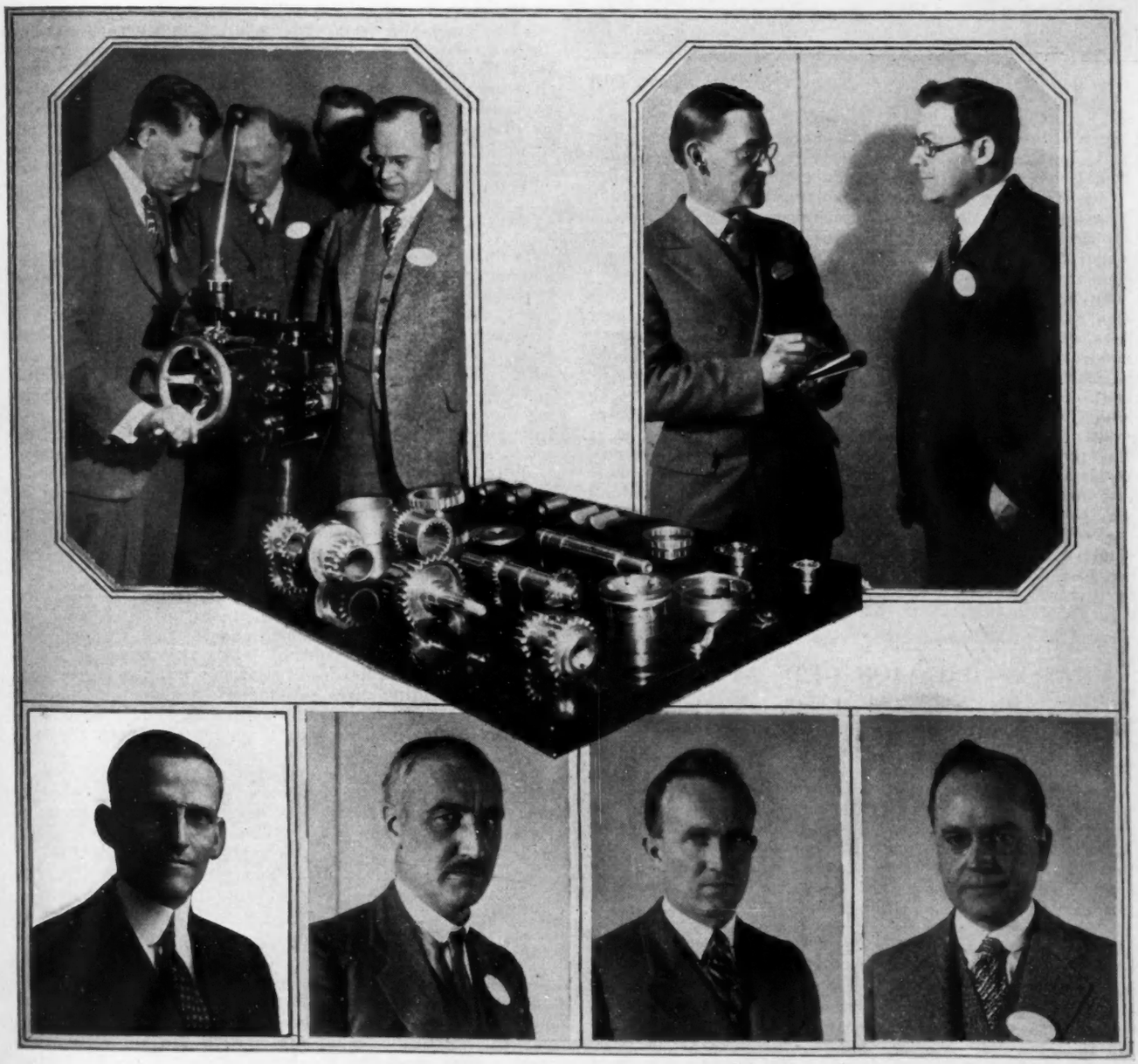
In discussing the paper on Four-Speed Transmissions, H. M. Crane said in part that he agrees with the main statements made but is inclined to question the statement to the effect that the industry has advanced far with regard to car performance. He said that the 1908 Packard car, an open touring-car, had fully the equivalent hill-climbing ability of most of our present cars, and about all the industry has been able to do since is to keep pace with the addition of car weight in the form of enclosed bodies, greater room, more accessories, more comforts, and with the ability to accelerate and to climb hills. After reviewing various phases of car development since 1908, Mr. Crane commended the statements made in the paper concerning the ease of shifting from third to fourth speed.

P. L. Tanney, of the Muncie Products Co., said that his company has built and tried out both the overgear and the direct fourth-speed gear in both the third-gear and in the internal-gear types, the result of its experience being to

favor the internal-gear transmission in connection with the direct fourth-gear. He also discussed in considerable detail questions relating to overgear and undergear features, as well as the subject of gearshifting. A. J. Scaife mentioned that for the last 17 years his company has been using both direct-third and direct-fourth transmission and is still using them. He elaborated this statement by stating reasons therefor. The indication of the discussion in general seems to be that the industry possibly may adopt four-speed transmission, because it permits ease of control between third and fourth-speed and shows a fuel economy greater by 20 per cent.

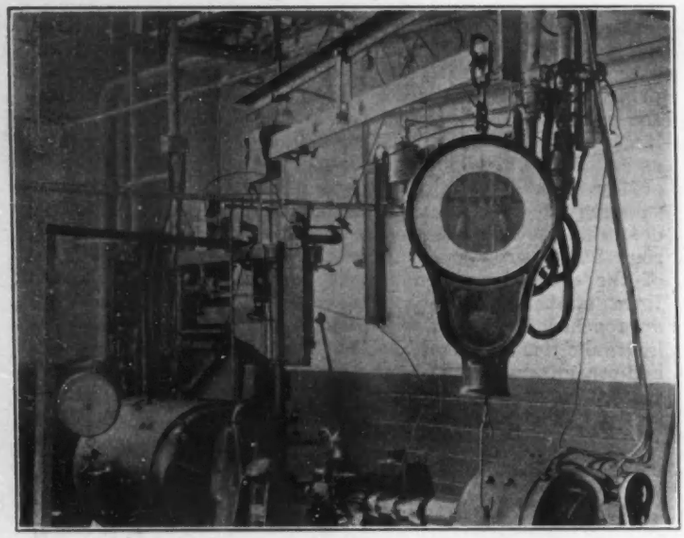
The Constantinesco Torque-Converter

The paper on the foregoing subject was presented by R. K. Jack, consulting engineer, Glasgow, Scotland, who said that Mr. Constantinesco had supplied the data, being himself unable to come to the United States at this time. The purpose of the converter is to produce an instant and automatic torque always equal to the resistance encountered, while the primary driving-engine maintains its torque and speed nearly invariable. After describing the elementary principles involved, these being in many respects similar to the principles that govern the movement of a simple pendulum. Mr. Jack said that the traction problem can be stated as follows: An engine that can develop a steady pull at a steady speed has to be used to drive against a resistance that requires a variable pull or a variable speed. From this definition, it is obvious that the engine must be connected to some intermediary machinery which will change the form of the energy supplied by the engine to some convenient form applied to the resistance. The problem has been approached in many ways, such as by using gearboxes, hydraulic transmissions, electric transmissions, friction discs, and other forms of mechanism by which it is possible to alter the conditions between the driving engine and the resistance in a way so that the work can be performed while maintain-



Participants in the Transmission Session

At the Bottom, from Left to Right, C. A. Neracher; H. M. Stevens, Chairman; Harold Nutt, and R. K. Jack. S. O. White and P. J. Tenney (Upper Right) Took an Active Part in the Discussion of the Neracher and Nutt Paper on Four-Speed Transmissions, Views of Which Are Shown Above



APPARATUS USED IN TESTING THE EFFICIENCY OF THE DURANT FOUR-SPEED TRANSMISSION

ing a steady pull and a steady engine-speed. The mechanical solution to this problem can be reduced to a very simple foundation; namely, to the principle of the lever.

Mr. Jack went on to give explanations and illustrations of details of development of mechanism that will accomplish the desired results, describing also the particular converter under discussion together with the theory pertaining to it. Numerous lantern-slide illustrations were presented.

In the course of the discussion and in reply to the question as to what effect the converter has on flywheel bearings when the car is stationary and the throttle is opened suddenly, Mr. Jack said that, in such a case, the load due to inertia is not very great because the levers are set 180 deg. apart. He said that possibly with heavier cars in which inertia forces must be greater, a disturbance due to excess loads and unbalanced forces probably would occur. The question was asked as to why it is necessary to convert reciprocating into rotary motion and then to reconvert it into reciprocating motion. Mr. Jack replied that the only way to obtain a variable between the rotating primary and the rotating secondary is by transformation out of the rotating stage. No other means exist whereby the torque can be graduated except by first obtaining a vibrating form of energy and transferring it away from direct-operating rotary-motion.

CHASSIS BEHAVIOR GETS ATTENTION

Rubber Spring-Mountings' Advantages and Pivot-Preventing Braking-System

Shimmy continues to be a very moot question, as was made evident by the unusual amount of animated discussion at the Chassis Section. This topic and a paper on car pivoting and another on rubber spring-mountings drew a gathering of 230 members on the afternoon of Jan. 28, fully one-quarter of whom remained ½ hr. overtime to hear and take part in the shimmy discussion, notwithstanding it was the last session of the meeting and the evening carnival at Oriole Terrace was prominently in the minds of all.

The first paper presented was on Rubber Spring-Mountings, by Walter C. Keys, who described the new mountings developed by the United States Rubber Co., illustrating them with lantern slides, and enumerated 15 advantages that he said they possess. Rubber, he said, functions as an ideal vibration damper and shock-absorber, and the new mounting is used not only in the spring-hangers of the chassis but has also been applied most successfully for supporting engines in passenger-cars, motorcoaches and motor-trucks, where it has the advantage of a non-metallic support that is not preloaded by any clamping means and has proved highly effective as a silencer and vibration damper. A dozen companies now have on the road vehicles fitted with the spring mountings and are checking the riding-qualities and roadability of the vehicles and the life of the mountings. Some of these vehicles have traveled more than 40,000 miles and given satisfactory performance.

As described by Mr. Keys, the new spring mounting consists of a pair of outwardly extending studs, threaded at their inner ends into steel plates that are surrounded by layers of reinforcing fabric. The fabric, plates and part of the studs are entirely encased in rubber of suitable composition to withstand the necessary distortion and have the requisite life. Among the advantages claimed for this type of spring mounting are that it reduces the high-frequency vibrations imparted through the tires and springs to the car body, requires no lubrication, eliminates shackle wear and rattle, obviates shackle adjustment, increases materially the life of the chassis springs, reduces noise between the running-gear and body, has a pleasing appearance, produces no bad effects on steering and brake-linkage, does not impair the roadability of the car, seems to lessen shimmy in some cases, decreases the cost of frames by eliminating expensive spring-brackets, reduces the cost of springs by eliminating bushings and all forming operations on the main leaves, is of moderate cost itself, causes no dangerous sidesway if intelligently applied to a vehicle, and reduces considerably the total number of parts in the spring connections.

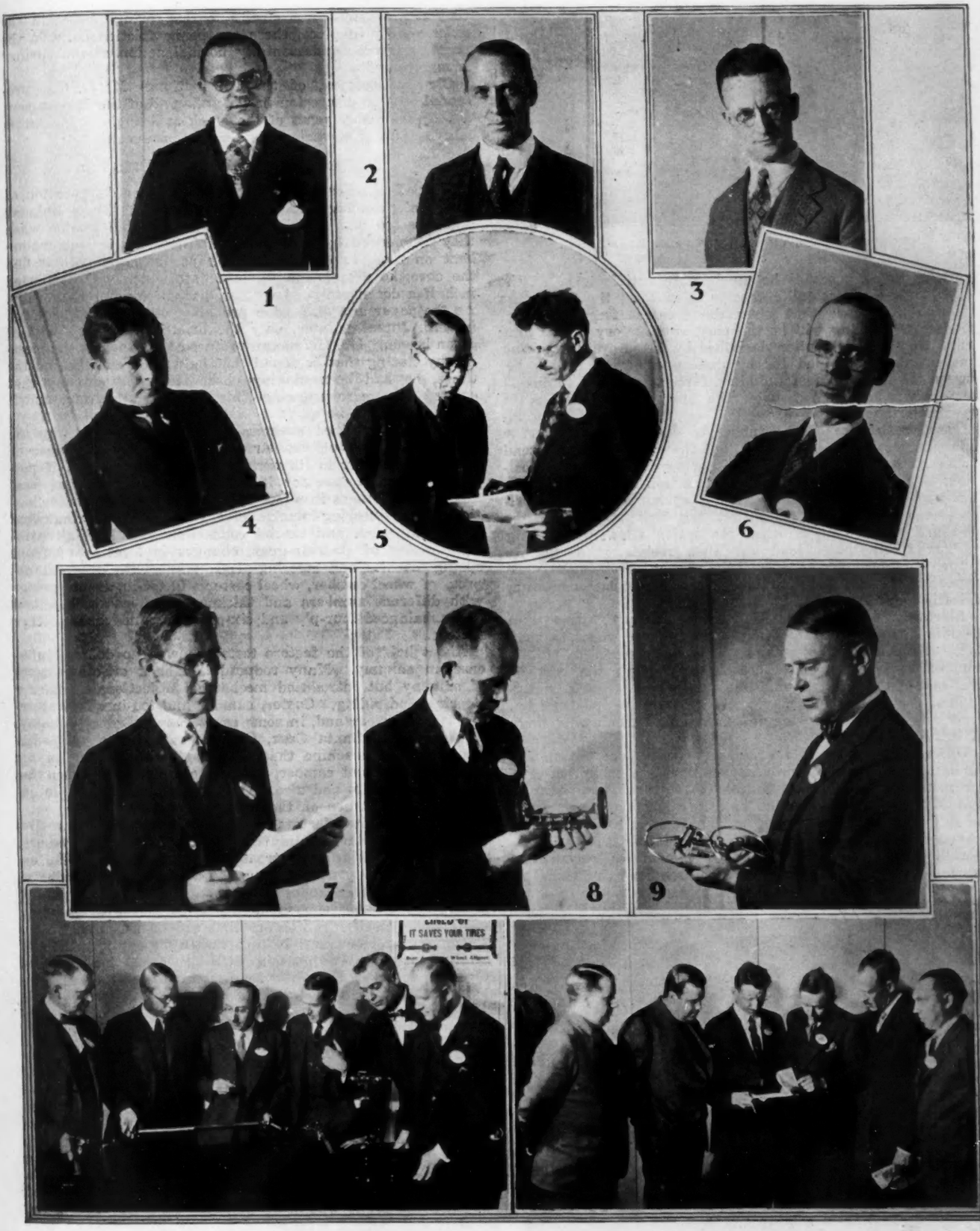
BALL-AND-SOCKET TYPE PREVENTS AXLES SHIFTING

The problem of controlling the front and rear axles against shifting longitudinally with relation to the frame was solved by development of the ball-and-socket type of shackle, in which one of the projecting studs is made with a ball on its inner end that engages in a socket secured to the other stud in such a way as to permit angular motion of one stud with relation to the other and also to permit compression and extension of the rubber while at the same time preventing forward, backward or lateral movement of one stud with relation to the other. The result produced is fully equivalent to that of a conventional spring-eye construction, said Mr. Keys, and a complete rubber insulation is provided between the ball and socket in the vertical plane. In all the experimentation that has been done in the industry to adapt rubber for spring connections, the instability of the axles has been most serious, as it affects steering and mechanically operated brakes.

A type of mounting similar in appearance to the foregoing but with the ball-and-socket feature eliminated has been developed for the unpivoted end of front springs. And for the rear end of rear springs, where the change in length of the spring due to flexure is relatively large, a higher type of spring mounting gives satisfactory results and possesses the advantage of adding slight lateral flexibility when driving over muddy roads which is comparable with the universal-joint that is placed at the rear of a three-quarter platform-spring. Satisfactory applications have been made to the cantilever rear construction and also to cross-spring construction as used in some cars. The development of these spring mountings has been carried on during the last 2½ years, with conferences at all stages with representatives of spring and frame manufacturers, and only during the last 4 months have the mountings been offered for sale to the industry.

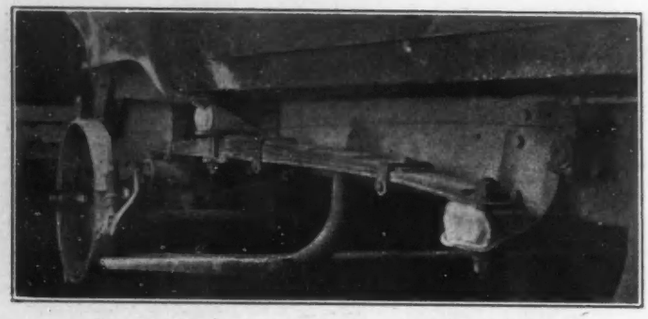
NEW BASIC PRINCIPLES INVOLVED

In presenting written discussion on the subject, Hazen L. Hoyt, Jr., of the Belflex Corporation, said that the use of non-metallic spring-connections is relatively new and presents basic principles that are new to the automotive engineer. New problems are being presented to the spring maker that will require modifications of the accepted laws of spring design, but once these are made, the action of the



ENGINEERS TAKING PROMINENT PART IN THE CHASSIS SESSION

H. E. Maynard, Chairman, and Karl L. Herrmann, Author (5); Walter C. Keys, Author (6); Johannes Plum, Author (4); B. J. Lemon (2), B. Darrow (3), J. F. Duby (7), J. S. Bushey (8), and H. W. Dammonn (9) Discussed the Herrmann Paper, and Charles Froesch (1) Discussed the Keys Paper. The Delegation from the Studebaker Engineering Staff Is Shown in the Lower Right Photograph

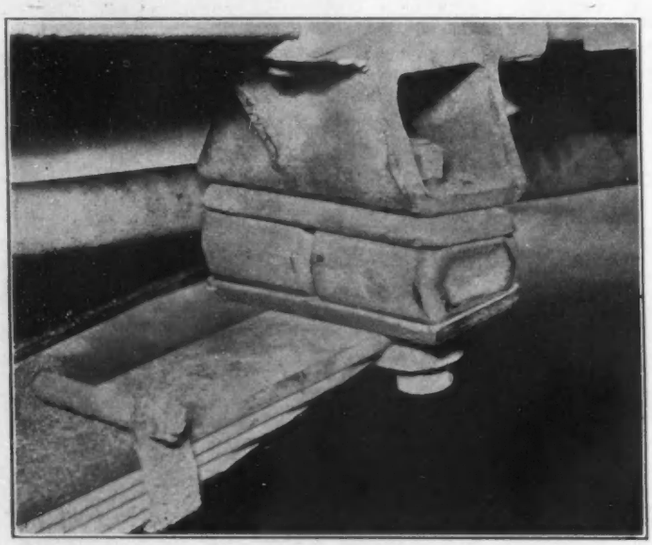


RUBBER MOUNTS ON PASSENGER-CAR REAR-SPRING

springs in service will be much more satisfactory, as the effect of the non-metallic shackle is uniform throughout its life. The shackle that gives the greatest freedom of action to the spring will be the most satisfactory in the long run. In the construction described by Mr. Keys, the spring movement is provided for by distortion of the rubber between the metal plates, and since force is required to distort the rubber, the effect upon the spring must be one of resisting the freedom of action, said Mr. Hoyt. The increased resistance of the rubber to distortion will exert a snubbing action on the spring, but the same force will tend to accelerate the return of the spring to its normal position, thereby imparting an uneven action that cannot help but upset all the accepted laws of spring action. Experience has proved, he said, that the best results can be obtained with snubbers when the action allows the spring to flex freely under load and then resists or delays its return to normal position. This seems to be exactly the opposite effect to that obtained with the rubber mounting described by Mr. Keys.

Sidesway is best controlled by the use of stiff rather than flexible springs, and the action of the shackle seems to have little effect upon this; spring rates alone seem to be the controlling factor. The shackle designed for the rear or free end of the spring would allow as much lateral as longitudinal movement and may reach undesirable proportions, especially in cars employing unusually long springs or springs of considerable camber.

Unless the rubber in the ball-and-socket type completely surrounds the ball, to prevent relative movement between the metallic parts, the connection ceases to be non-metallic, and if it does surround the ball it would seem necessary to secure the rubber to the metal parts to avoid relative movement, Mr. Hoyt pointed out. Of various types of non-metallic shackle on the market, those made of rubberized-fabric seem most nearly to fulfill the required condition, as they resist lateral movement of the spring, maintain the axles rigidly in place, there can be no friction between the parts, and the fundamentally normal action of the springs is maintained.



APPLICATION OF TWO U. S. RUBBER MOUNTS TO MOTOR-TRUCK SPRING

Charles Froesch, of the International Motor Co., presented written discussion in which he told of the development during the last 7 years of the Mack rubber shock insulators and the effects of various details of construction.

SHIMMY PROBLEM WARMLY DEBATED

When K. L. Herrmann, of the Studebaker Corporation of America, presented his paper on Causes of Wheel Shimmy and asserted that tire makers had created the trouble when they introduced balloon tires and therefore it was incumbent on them to determine the cause of shimmy and find the cure, he provoked a warm debate which was conducted in half a dozen extended written discussions and also orally. As the paper and discussion probably will be printed in full in THE JOURNAL later, only the briefest summary will be given herein. Mr. Herrmann prefaced his paper at the meeting by stating that he found that he was 3 years behind the times, he had been making observations on shimmy that existed 3 or more years ago, his paper is all wrong and it was admitted to be so.

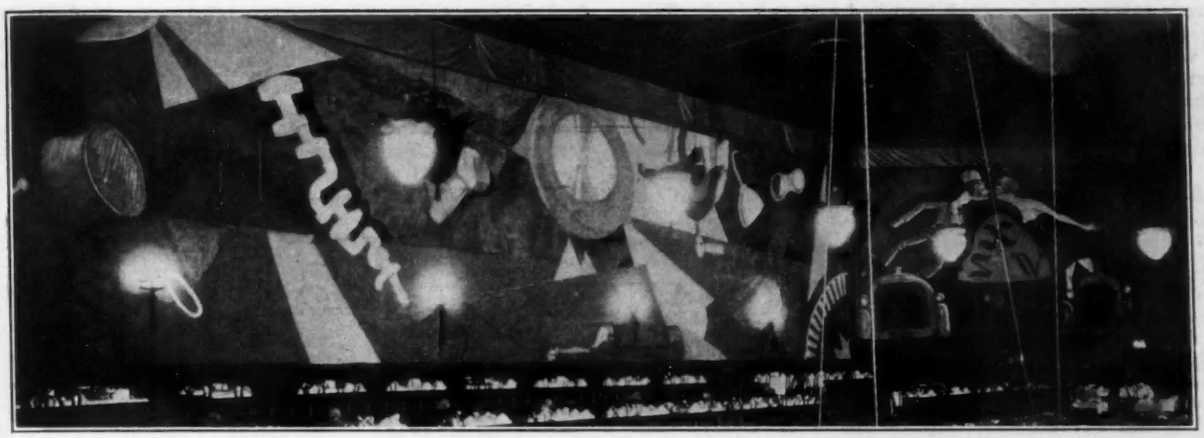
He then described a series of many tests made by the Studebaker research department to determine the cause or causes of shimmy in its various manifestations and, if possible, to find a cure for it. These tests included a great number of changes in offset of axles and wheels, in inclination of the steering-knuckle pivot, the use of springs and rubber in reach and tie-rod connections, trial of all principal makes of steering-gear, changes in location of front spring-shackles and steering-arms, trials with different degrees of wheel camber, wheel caster and toe-in, front springs with different numbers and thicknesses of leaves, balanced and unbalanced four-ply and six-ply tires, and various other factors.

About half of the factors tested showed no definite influence on shimmy. Many reduced kick-back or other types of shimmy but introduced mechanical objections or harder steering and riding. Caster, camber and toe-in affect steering and tire wear and, in some cases, may influence shimmy. A company in Santa Cruz, Cal., he said, has developed a wheel-aligning machine that, combined with apparatus for setting caster and camber, gives a complete correction for all three elements and also an indication as to probable action of the car when on the road.

The fundamental factors creating shimmy are in the tire, the speaker declared, and these are balance, air-pressure, run-out, and variation of tread thickness. It has been established definitely that various car designs do not strike at the fundamental cause of the trouble, and engineers have wasted considerable time in trying to correct with damping and friction devices the errors that are in the tires. Solution of the problem must be undertaken, he said, by the tire manufacturers in conjunction with the wheel makers, and he also put up to them the related problems of correct inflation-pressures and tire life.

CAR AND TIRE MAKERS' COMMON PROBLEMS

In the discussion B. J. Lemon, of the United States Rubber Co., and B. Darrow, of the Goodyear Tire & Rubber Co., rose to the defense of the tire makers. Mr. Lemon told at some length to the extensive physical and other tests that are made of finished tires in the factory, of work that has been done to improve the tires, and said that 3 years ago his company began to balance tires with special balancing machinery designed for the purpose. The industry as a whole, however, knows too little about the mechanics of alignment of front wheels as affecting steering, tire wear, shimmy, and general stability of the car in operation. Disquieting rumors are widespread that the amounts of toe-in, pitch and caster on new cars do not accord with published specifications; makers of aligning instruments say that shimmy can be largely eliminated by proper front-wheel alignment and axle tilt.



SOME OF THE "DELIRIOUSLY AUTOMOTIVE" DECORATIONS AT ORIOLE TERRACE

Mr. Darrow quoted R. B. Day, of the research department of his company, as saying that the danger of shimmy will exist as long as automobiles carry heavy weights in the front wheels freely suspended between upper and lower springs, that is, the body springs and the tires. Another cause is the bringing of the center of contact of the tire with the road very close to the vertical axis of the king-pin, which makes it very easy for the balloon tire to deflect to either side of the king-pin axis and produce a rapidly reversing steering-wheel whip. Mr. Darrow concluded by saying that he doubts very much if many engineers believe that shimmy can be remedied by changes in tire design alone.

W. R. Griswold, of the Packard Motor Car Co., said that four sets of forces enter into the shimmy problem: (a) exciting forces, (b) restoring forces, (c) inertia, and (d) damping forces, and the phenomena of shimmy can be expected under any condition where the exciting force and the damping force are not in static equilibrium. One of the primary exciting forces is brought into play because of poor steering geometry and can be exceedingly large when the geometry is much in error. He gave the following as practical ways of overcoming shimmy with conventional front-end construction:

(1) Balance wheels and tires to close limits
(2) Design the steering system for the minimum error of steering geometry.
(3) Reduce the flywheel effect of front-wheel assemblies to the minimum.
(4) Use stiff frame-construction, especially as to torsional stiffness.
(5) Take advantage of all the damping action possible, such as interleaf friction of the front springs.
(6) Make the steering linkage as stiff as possible consistent with weight and other restrictions.

Written discussion was also submitted by John F. Duby, who said that his experience in eliminating shimmy seems to confirm his belief that something in the mechanical construction of certain cars makes them more subject to shimmy than cars of other makes.

H. W. Dammann, of the Bear Mfg. Co., dealt at length with the lack of attention of car builders to axle and wheel alignment of new cars as delivered to dealers and told of his work with dealers in correcting, with an axle gage, the caster of the axle as well as the pitch and toe-in of the wheels.

Considerable impromptu oral discussion supplemented the written discussion and was participated in by the foregoing speakers and also by Messrs. Chandler, Bushby and Huebotter.

BRAKING SYSTEM TO PREVENT PIVOTING

An interesting new theory of the causes of pivoting and a suggested means of preventing the disturbing and dangerous phenomenon was presented by Johannes Plum. His paper is printed in full in subsequent pages of this issue of THE JOURNAL. In essence he maintained that the use of front-wheel brakes alone is not dangerous because, so long as the rear wheels continue to revolve, the car cannot pivot, but that the use of both front and rear-wheel brakes simultaneously is dangerous if the braking pressures are not combined in correct proportion. Different braking conditions are presented by wet roads and dry roads. On dry roads, when using four-wheel brakes, the problem is to distribute the braking force to the front and rear wheels in such proportions that in spite of the transfer of weight from the rear to the front of the car, due to centrifugal force, too violent a stop will not be made and a "fair-weather" pivot caused. With two-thirds of the force applied to the rear wheels, the preponderance of stopping force will remain active behind the center of gravity. On slippery roads two-thirds of the force should be transferred to the front wheels so that the front wheels will lock momentarily before the rear wheels and all pivoting forces will be eliminated. Steering can always be recovered then by releasing the brakes momentarily.

In the discussion he said that with a system of hydraulic brakes he has two cylinders with an equalizing bar between them on which he can shift the distribution by a pull-rod on the instrument board. If the road is skiddy the rod is pulled out and left in that position. When the road becomes dry, the rod is pushed in. So long as the rod is out, the driver will not forget it and neglect to push it in when the slippery condition of the road ceases to exist.

RECORD ATTENDANCE AT 1927 CARNIVAL

Novel Entertainment and Deliriously Automotive Decorations Enhance Merriment

The 1927 Carnival Committee, under the able chairmanship of E. V. Rippingille, may well be satisfied with the success of the Carnival, which boasted an attendance of 1152. The Carnival Committee planned an unusual program of entertainment, and the decorations, designed by Chairman Rippingille, and justly described as "deliriously automotive" aptly depicted the carnival spirit, which was caught by everyone present and which in itself was the one factor that made the Carnival a glorious good time instead of just a party.

Many and varied were the favors that were to be found. One eagle-eyed engineer even found a glittering bracelet, which is now being held at the Society office, awaiting identification. Klaxon horns were distributed, for the express purpose, or so it seemed, of aiding the orchestra when it showed signs of weariness. For while a mere saxophone player may tire after a while, an engineer performing on a Klaxon goes on forever.

Then, of course, there was the monkey dance. The steps

are very easy—merely a high leap and a strong hold. There were approximately 500 engineers and 500 ladies. Each lady wanted a monkey. There were 150 monkeys. The rest is merely a matter of imagination and simple arithmetic.

What is it that makes a good Carnival? Hard work by an able Committee—that was there. A gay crowd, a smooth floor, a good orchestra, and the merry Carnival spirit—all were there in full measure. According to those present, it was the best one ever, and many and sincere are the congratulations to the Committee which made it possible.

Keen appreciation is due Walter C. Keys and W. R. Strickland for the novel canvas drops that covered the walls; to Phil N. Overman for the orchestras; to W. R. Flannery for the chorus numbers and other entertainment and to F. W. Marschner for the favors and for the excellent seating arrangements. The other members of the Committee were F. A. Cornell, H. N. Davock, H. T. Ewald, L. C. Hill, M. P. Rummey, and George Stone.

DIMENSIONAL CHANGES OF TOOL STEELS

PREVIOUS determinations of the volume changes on hardening have shown that all steels increase in specific volume on quenching, provided the quantity of austenite retained is not exceptionally high. The work on cylinders, 1 in. in diameter and 4 in. long, of various tool-steel compositions, investigated at the suggestion of the Gage Steel Committee, has confirmed those observations. Length and diameter measurements have also shown that the volume change is mostly in diameter with surface-hardened steels which may even shrink in length. With full-hardened steels, the volume change is mostly in length when the quenching temperature is low but, if it is high, the unit diameter-change is greater than the unit length-change. In tempering, the unit changes in fully-hardened steels are practically the same in length as in diameter, this is not the case for surface-hardened cylinders, which change more in length than in diameter.

Three stages of volume change on tempering low alloy-content tool-steels have been recognized previously. First, a contraction which reaches the minimum on tempering 1 hr. at between 150 and 200 deg. cent. (302 and 392 deg. fahr.); second, an expansion to the maximum at about 260 deg. cent. (500 deg. fahr.); and, third, a contraction to the minimum at a temperature between 400 and 500 deg. cent. (752 and 932 deg. fahr.), at which minimum the density of the steel has returned to that in the annealed condition. The final contraction is at least twice as great as the initial one and appears to be simply a continuation of the first. That the contraction is caused by the decomposition of martensite and the expansion by the transformation of austenite to martensite has been shown.

The presence of austenite within the martensitic matrix of normally hardened tool-steels appears to be due to the pressure developed when austenite transforms against a surrounding martensite network during the latter part of the hardening transformation. The pressure increases, in tempering, with the shrinkage of the martensite matrix in the first stage of tempering. This apparently accounts for the somewhat abrupt start of the following expansion or second stage. The pressure relations existing during the first stage of tempering appear also to accelerate the decomposition of martensite.

From the dimensional changes on tempering, it was observed that the initial contraction, first stage, is greater with water-quenching than with oil-quenching and with a high quenching temperature than with a low, while the final contraction, third stage, was little affected by these variables. The expansion in the second stage was greater, the higher the quenching temperature was so long as an excess of carbide was present, but was slightly lower for water-quenching than for oil-quenching. The initial contraction was practically eliminated and the expansion further intensified by interrupting the oil-quench and cooling through the hardening transformation in air.

The implication of the above observations, that more austenite is retained by slow cooling through the hardening transformation than by fast, was confirmed by X-ray spectrum-analysis. The apparent cause of this phenomenon is the development of pressure sufficient to retard the transformation at an earlier stage with slow cooling than with fast, because of the shrinkage of the martensite matrix produced by transient tempering on slow cooling through Ar_2.

Time-changes were measured for aging at 100 deg. cent. (212 deg. fahr.) and at ordinary temperatures. All continuously quenched and untempered steels contracted with time; the rate of contraction was much greater when aged at 100 deg. cent. (212 deg. fahr.). Specimens cooled in air through the hardening transformation expanded with time but not definitely faster at 100 deg. cent. (212 deg. fahr.) than at ordinary temperatures. That continuously quenched steel will expand with time also if it be tempered to the start of the expansion is possible.

The magnitude of the initial contraction is no criterion of the permanence of hardened tool-steel, for it can be consummated by tempering to the first minimum. The chief problem of constancy is to avoid expansion, which is not a large effect in water-quenched steels but may reach considerable magnitude with oil-quenching; certainly so, if the cooling be retarded during the hardening transformation. Grounds exist for the belief that the expansion, caused by the transformation of austenite, can be completed by repeated heating and cooling through an approximate temperature cycle. Lacking the accelerating effect of austenite, the rate of decomposition of martensite and of the attendant contraction is extremely small at ordinary temperatures and probably negligible for all practical purposes.—Summary of paper by Howard Scott, presented by permission of the Director of the Bureau of Standards, before American Society for Steel Treating.

DRIVERS' WARNING SIGNALS

In the new traffic regulations for New York City the following rules for drivers' warning signals are given:

A driver immediately before stopping, slowing up or making a right or left turn shall give timely and unmistakable signals by a mechanical device or by using the following hand signals:

Right Turn.—Arm extended from side of car and pointed upward.

Left Turn.—Arm extended from side of car and pointed straight out.

Stopping or Slowing Up.—Arm extended from side of car and pointed downward.

Backing.—A driver before backing shall give timely and ample warning.

Starting.—A driver before starting from a curb shall indicate by hand or mechanical device the direction of turn into traffic.

Applicants *for* Membership

The applications for membership received between Dec. 15, 1926, and Jan. 15, 1927, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ARMOUR, JAMES D., metallurgist, Union Drawn Steel Co., *Beaver Falls, Pa.*

BALLANTINE, NOTEN D., assistant to president, Seaboard Air Line Railway, *Baltimore.*

BARTHOLOMEW, EARL, head of automotive department, Ethyl Gasoline Corporation, *New York City.*

BELL, STANLEY A., draftsman, Cadillac Motor Co., *Detroit.*

BERRY, RALPH, service representative, Reo Motor Car Co., *Lansing, Mich.*

BIXEL, EDWARD C., engineer, American Telephone & Telegraph Co., *New York City.*

BLACKWOOD, ALBERT J., mechanical engineer, International Motor Co., *Long Island City, N. Y.*

BLOOMSBURG, HARRY E., assistant consulting technologist to manufacturing department, Standard Oil Co. of New Jersey, *New York City.*

BOYD, THOMAS A., research engineer and head of fuel section, General Motors Corporation, *Detroit.*

BRAND, CHARLES LEEF, vice-president, Davis Welding & Mfg. Co., *New York City.*

BRONK, GEORGE R., assistant engineer, Maxmoor Corporation, *Newark, N. J.*

BURKLE, W. M., assistant engineer and draftsman, New York Telephone Co., *New York City.*

CASTLE, CHARLES C., vice-president, American Car & Foundry Motors Co., *New York City.*

CORBY, HAROLD V., machinist-instructor, California State Highway Commission, *Lankershim, Cal.*

CRABB, D. E., engineer, Dodge Bros., Inc., *Detroit.*

DELL, GERALD F., assistant to supervisor of motor-vehicle service, Pennsylvania Railroad Co., *Philadelphia.*

DOWSETT, FRED R., manager, Fuller & Sons Mfg. Co., *Kalamazoo, Mich.*

DRINKWATER, R. H., engineer, AC Spark Plug Co., *Flint, Mich.*

DUNN, HARRY BENJAMIN, automotive mechanic, Ottawa Car Mfg. Co., *Ottawa, Ont., Canada.*

EMMERT, RODGER J., factory manager, Dayton Engineering Laboratories Co., *Dayton, Ohio.*

FINN, WILLIAM J., engineer, Maxmoor Corporation, *Newark, N. J.*

FITCH, BENJAMIN F., president, Motor Terminals Co., *New York City.*

FITZGIBBON, JOHN J., specification engineer, Yellow Truck & Coach Mfg. Co., *Pontiac, Mich.*

FLUM, R. A., assistant general manager, C. G. Spring & Bumper Co., *Detroit.*

FRASER, T. C., assistant superintendent of motor equipment, Standard Oil Co. of New Jersey, *Baltimore.*

FREERS, GEORGE H., assistant chief engineer, Marmon Motor Car Co., *Indianapolis.*

GAMBLE, WILLIAM J., JR., secretary-treasurer and manager, Vulcan Steam Forging Co., *Buffalo.*

GORDON, L. O., president and manager, L. O. Gordon Mfg. Co., *Muskegon, Mich.*

GRIFF, GEORGE H., JR., chief mechanic, H. Piper Co., *Chicago.*

GROSS, W. A., electrical engineer, Nash Motors Co., *Kenosha, Wis.*

HADAWAY, W. S., engineer, Edison Lamp Works, *Harrison, N. J.*

HILDEBRAND, H. EDWARD, mechanical engineer, Continental Baking Corporation, *New York City.*

HUSTED, ELBERT E., sales engineer, Titeflex Metal Hose Co., *Newark, N. J.*

JAHN, EDWARD W., superintendent of transportation, Consolidated Gas, Electric Light & Power Co., *Baltimore.*

JOHNSON, GEORGE A., branch manager, North East Service, Inc., *New York City.*

KANE, M. J., proprietor repair shop, *Seattle.*

KIELY, THOMAS J., designer, checker and assistant chief draftsman, American Bosch Magneto Corporation, *Springfield, Mass.*

KUNS, RAY F., principal, Automotive Trades School, and editor, *Automobile Digest, Cincinnati.*

LEIBHOLZ, KARL, mechanical engineer, *Detroit.*

LEIPERT, EDWARD, draftsman, International Motor Co., *Long Island City, N. Y.*

LINK, CHARLES W., assistant body engineer, Studebaker Corporation of America, *South Bend, Ind.*

LLORENS, CARLOS A., mechanical engineer, *New York City.*

MASON, GEORGE E., test engineer, Multibestos Co., *Walpole, Mass.*

MCCOY, HENRY, general manager, Canadian Radiators, Ltd., *Hamilton, Ont., Canada*

MCKEE, SAMUEL A., assistant mechanical engineer, Bureau of Standards, *City of Washington.*

MCMANUS, FRANK C., chief engineer, Morrissey Motor Car Co., *Bridgeport, Conn.*

MILLER, C. R., consulting engineer, White Star Refining Co., *Dayton, Ohio.*

MORGAN, WILLIAM A., service manager, Utter Motor Co. and Stutz Sales Co., *Denver.*

NICHOLSON, FREDERICK G., service engineer, John Warren Watson Co., *Philadelphia.*

NIDIVER, E. R., fixed representative, American Bosch Magneto Corporation, *Chicago.*

OLSON, ARVID, instructor of automobile mechanics, Independent School District No. 39, *Eveleth, Minn.*

PARKINS, WRIGHT, associate mechanical engineer, engineering division, Air Corps, McCook Field, *Dayton, Ohio.*

POORE, MORRIS C., service manager, Fageol Motors Co., *San Francisco.*

PORTER, JAMES G., sales manager, International Harvester Co., *San Francisco.*

REEVES, CLIFTON, industrial engineer, *New York City.*

RUNDQUIST, GUST, detailer, Locke & Co., *Rochester, N. Y.*

SCHMID, ERNEST, engineer and general director, Usines S. R. O., *Annecy, Haute-Savoie, France.*

SCOTT, HERBERT WESLEY, truck specialist, General Motors Export Co., *New York City.*

SPOONER, F. E., editorial representative, McGraw-Hill Co., *New York City.*

STEINBERGER, MARISON F., special engineer, Baltimore & Ohio Railroad, *Baltimore.*

STERLING, C. H., automotive engineer, General Motors Corporation Research Laboratories, *Detroit.*

THAETE, MAX W., service manager, Allison Motors, Inc., *Denver.*

TROENDLY, H. P., chief engineer, William D. Gibson Co., *Chicago.*

TYSON, THEODORE J. W., draftsman, McCord Radiator & Mfg. Co., *Detroit.*

TURNER, RAYMOND GEORGE, technical assistant, Rover Co., Ltd., *Birmingham, England.*

UNDERWRITERS LABORATORIES, *Chicago.*

WATERS, GUY WILLIAM, district sales manager, Timken Roller Bearing Co., *Canton, Ohio.*

WATTS, C. A., Pacific Coast representative of the Waukesha Motor Co. and the Racine Radiator Co., *San Francisco.*

WERNER, OSCAR, section engineer, Westinghouse Electric & Mfg. Co., *South Bend, Ind.*

WILSON, MILTON W., superintendent of engineering, Curtiss Air Station of Atlantic City, *Atlantic City, N. J.*

ZAP, EDUARD, mechanical engineer, General Motors Corporation Research Laboratories, *Detroit.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Dec. 10, 1926, and Jan. 10, 1927. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member.

BOLTE, F. B. (A) salesman, East Side Nash, *East St. Louis, Ill.;* (mail) 1212 College Avenue.

BOSSARD, J. M. (A) manager, Alvord-Polk Tool Co., *Millersburg, Pa.*

BOTHELL, GEORGE (A) service superintendent, Mack-International Motor Truck Corporation, *Seattle;* (mail) 1717 Eighth Avenue, North.

BRUKNER, C. J. (M) general manager and treasurer, Advance Aircraft Co., *Troy, Ohio.*

CLAKIDGE, GEORGE CHARLES (A) service manager, General Motors Export Co., 224 West 57th Street, *New York City.*

CLARKE, JOSEPH G. (A) sales engineer, Delco-Remy Corporation, *Dayton, Ohio;* (mail) 1233 Carlisle Avenue.

COOLEY, JAMES H. (M) superintendent of branch-house motor-truck equipment, Armour & Co., *Chicago;* (mail) 5361 Cottage Grove Avenue.

CORDERY, THOMAS (F M) automotive engineer, Vauxhall Motors, Ltd., *Luton, Bedfordshire, England;* (mail) 89 Ashburnham Road.

DAWSON, CHARLES (A) assistant technical engineer, Yellow Truck & Coach Mfg. Co., *Pontiac, Mich.*

DONNAY, JEAN (F M) manager, Societe Anonyme des Anciens Etablissements Chenard & Walcker, Rue du Moulin de la Tour, *a Gennevilliers, Seine, France.*

FARMER, CHARLES D. (A) superintendent of equipment, State Highway Commission, *Raleigh, N. C.*

GILLMORE, BRIGADIER-GEN. WILLIAM E. (S M) chief of materiel division, Air Corps, McCook Field, *Dayton, Ohio.*

HANSA, CHARLES (A) service manager, Bonwit, Teller & Co., New York City; (mail) 91 Hillcrest Street, *Great Kills, Staten Island, N. Y.*

HARPER, HUBERT CHARLES (F M) service manager, Ford Motor Co. of India, Ltd., P. O. Box No. 499, *Bombay, India.*

KOEHLER, ROLAND C. (A) technical engineer ,Yellow Truck & Coach Mfg. Co., *Chicago;* (mail) 5000 Oakdale Avenue.

MCCUEN, CHARLES L. (M) designing engineer, engineering department, Olds Motor Works, *Lansing, Mich.*

MIDDLEWORTH, HENRY V. (A) superintendent of transportation, Consolidated Gas Co. of New York, 130 East 15th Street, *New York City.*

MILLER, WELLINGTON EVERETT (J) designing engineer and custom coach work, Hollywood Coach Co., Inc., *Glendale, Cal.;* (mail) 360 West Magnolia Avenue.

PARNELL, FRANK GORDON (F M) automobile designer, Triumph Cycle Co., Ltd., *Coventry, England;* (mail) 15 Spencer Avenue.

ROGERS, WALTER S. (A) assistant repair service engineer, White Motor Co., 842 East 79th Street, *Cleveland.*

SARGENT, ALBERT M. (M) plant engineer, C. G. Spring & Bumper Co., 2660 East Grand Boulevard, *Detroit.*

SARGENT, FRED L. (M) sales manager, White Co., 11th and Mission Streets, *San Francisco.*

SCHAFER, O. H. (A) gear specialist in sales and service division Celoron Co. division of Diamond State Fibre Co., 1656 Besley Court, *Chicago.*

SENTZ, IRVIN H. (A) service manager, C. H. Reeves & Co., Inc., 1315 Cathedral Street, *Baltimore.*

SLATTER, ALBERT J. (A) tire designer, Dunlop Tire & Rubber Corporation of America, *Buffalo;* (mail) 152 Stratford Road.

WALTON, KENNETH B. (J) Panmure Road, *Haverford, Pa.*

WAWRZINIOK, OTTO C. E. P. (F M) professor, Technical University, *Dresden, Germany.*

WHEELER, WILLIAM H. (A) president, Fedco Number Plate Corporation, 12 East 41st Street, *New York City.*